INSTITUTION

OF

MECHANICAL ENGINEERS.

28058

PROCEEDINGS.

1868.

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81 NEWHALL STREET, BIRMINGHAM.

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WILLIAM P. MARSHALL,
Institution of Mechanical Engineers,
81 *Newhall Street, Birmingham.*

LIST OF MEMBERS,

WITH YEAR OF ELECTION.

1868.

MEMBERS.

1861. Abel, Charles Denton, 20 Southampton Buildings, London, W.C.
1866. Adams, William, Locomotive Superintendent, North London Railway, Bow, London, E.
1848. Adams, William Alexander, Newbold Beeches, Leamington.
1859. Adamson, Daniel, Newton Moor Iron Works, Hyde, near Manchester.
1861. Addenbrooke, George, Rough Hay Furnaces, Darlaston, near Wednesbury.
1851. Addison, John, 6 Delahay Street, Westminster, S.W.
1858. Albaret, Auguste, Engine Works, Liancourt, Oise, France.
1847. Allan, Alexander, Bridge Street, Worcester.
1865. Allen, William Daniel, Bessemer Steel Works, Sheffield.
1865. Alleyne, John Gay Newton, Butterley Iron Works, Alfreton.
1867. Allibon, George, Rosherville Iron Works, Northfleet, near Gravesend.
1859. Alton, George, Midland Road, Derby.
1861. Amos, Charles Edwards, 5 Cedars Road, Clapham Common, London, S.W.
1867. Amos, James Chapman, Grove Works, Southwark Street, London, S.E.
1856. Anderson, John, Superintendent of Machinery to the War Department, Royal Arsenal, Woolwich, S.E.
1856. Anderson, William, Erith Iron Works, Erith, Kent, S.E.
1862. Angus, Robert, Locomotive Superintendent, North Staffordshire Railway, Stoke-upon-Trent.
1858. Appleby, Charles Edward, Renishaw Colliery, near Chesterfield.
1867. Appleby, Charles James, Emerson Street, Southwark, London, S.E.
1859. Armitage, William James, Farnley Iron Works, Leeds.
1866. Armstrong, George, Great Western Railway, Locomotive Department, Wolverhampton.
1863. Armstrong, John, Timber Works, 17 North Bridge Street, Sunderland.
1857. Armstrong, Joseph, Locomotive Superintendent, Great Western Railway, Swindon.
1858. Armstrong, Sir William George, Elswick, Newcastle-on-Tyne.
1857. Ashbury, James Lloyd, 9 Sussex Place, Hyde Park Gardens, London, W.

1865. Bagshawe, John J., Thames Steel Works, Sheffield.
1865. Bailey, John, Blackhall Place Iron Works, Dublin.
1860. Bailey, Samuel, Mining Engineer, The Pleck, near Walsall.
1866. Baines, William, London Works, Soho, near Birmingham.
1866. Baker, Samuel, 22 Oil Street, Liverpool.
1865. Baldwin, Martin, Bovereux Iron Works, Bilston.
1860. Barclay, John, Bowling Iron Works, near Bradford, Yorkshire.
1865. Barclay, William, 4 College Lane, Liverpool.
1866. Barker, George, Messrs. Barker and Cope, Kidsgrove, Stoke-upon-Trent.
1860. Barker, Paul, Old Park Iron Works, Wednesbury.
1866. Barnard, Clement, 11 Billiter Square, London, E.C.
1862. Barrow, Joseph, Whalley Chambers, 88 King Street, Manchester.
1867. Barrows, Thomas Welch, Portable Engine Works, Banbury.
1862. Barton, Edward, Carnforth Hæmatite Iron Works, Carnforth, near Lancaster.
1865. Bass, William, Sanitary Pipe Works, Parkgate, near Rotherham.
1860. Batho, William Fothergill, 36 Lancaster Street, Birmingham.
1859. Beacock, Robert, Victoria Foundry, Leeds.
1865. Beardshaw, Charles C., Baltic Steel Works, Sheffield.
1848. Beattie, Joseph, Locomotive Superintendent, London and South Western Railway, Nine Elms, London, S.W.
1867. Beaumont, Captain Frederick, R.E., Royal Engineer Office, Sheerness.
1859. Beck, Edward, Messrs. Neild and Co., Dallam Iron Works, Warrington. (*Life Member.*)
1862. Beckett, Henry, Mining Engineer, Upper Penn, Wolverhampton.
1864. Beckton, James George, Whitby, Yorkshire.
1865. Bell, Charles, North Staffordshire Railway, Locomotive Department, Stoke-upon-Trent.
1867. Bell, George, Soho Iron Works, Bolton.
1858. Bell, Isaac Lowthian, Clarence Felling and Wylam Iron Works, Newcastle-on-Tyne.
1865. Bell, John, Addison Villa, Timperley, near Manchester.
1857. Bellhouse, Edward Taylor, Eagle Foundry, Hunt Street, Oxford Street, Manchester.
1868. Belliss, George Edward, Agricultural Engine Works, Broad Street, Birmingham.
1865. Bennett, Henry, Hadley Lodge, near Wellington, Shropshire.
1854. Bennett, Peter Duckworth, Spon Lane Iron Foundry, Westbromwich.
1865. Benson, George Henry, Stalybridge.
1867. Berkley, George, 9 Victoria Chambers, Victoria Street, Westminster, S.W.
1867. Bernhardt, George, Stand Lane, Radcliffe, near Manchester.
1861. Bessemer, Henry, 4 Queen Street Place, New Cannon Street, London, E.C.

1866. Bevis, Restel Ratsey, Birkenhead Iron Works, Birkenhead.
1847. Beyer, Charles F., Messrs. Beyer Peacock and Co., Gorton Foundry, Manchester.
1861. Binns, Charles, Mining Engineer, Clay Cross, near Chesterfield.
1863. Birckel, John James, Regent's Canal Iron Works, Eagle Wharf Road, London, N.
1866. Birkbeck, John Addison, Sheepbridge Iron Works, Chesterfield.
1847. Birley, Henry, Haigh Foundry, near Wigan.
1856. Blackburn, Isaac, Witton Park Iron Works, Darlington.
1851. Blackwell, Samuel Holden, Dudley.
1865. Bladen, Charles, Provan Mill House, Springburn, near Glasgow.
1862. Blake, Henry Wollaston, Messrs. James Watt and Co., 18 London Street, London, E.C.
1867. Bleckly, John James, Bewsey Iron Works, Warrington.
1862. Blyth, Alfred, Steam Engine Works, Fore Street, Limehouse, London, E.
1863. Boeddinghaus, Julius, Messrs. Heinrich Boeddinghaus and Sons, Elberfeld, Prussia.
1862. Bouch, Thomas, 78 George Street, Edinburgh.
1858. Bouch, William, Shildon Engine Works, Darlington.
1847. Bovill, George Hinton, 24 Duke Street, Westminster, S.W.
1858. Bower, John Wilkes, Lancashire and Yorkshire Railway, Engineer's Office, Manchester. (*Life Member.*)
1862. Boyd, Nelson, Belfast Foundry, Donegal Street, Belfast.
1854. Bragge, William, Atlas Steel and Iron Works, Sheffield.
1854. Bramwell, Frederick Joseph, 37 Great George Street, Westminster, S.W.
1868. Breeden, Joseph, 156 Cheapside, Birmingham.
1848. Broad, Robert, Horseley Iron Works, near Tipton.
1865. Brock, Walter, Vulcan Foundry, Glasgow.
1852. Brogden, Henry, Sale, near Manchester. (*Life Member.*)
1866. Brown, Andrew Betts, 80 Cannon Street, London, E.C.
1866. Brown, Charles James, Unity Chambers, Temple Street, Birmingham.
1865. Brown, George, Rotherham Iron Works, Rotherham.
1863. Brown, Henry, Metropolitan Carriage and Wagon Co., Saltley Works, Birmingham.
1847. Brown, James, Jun., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1850. Brown, Sir John, Atlas Steel and Iron Works, Sheffield.
1853. Brown, Ralph, Patent Shaft Works, Wednesbury.
1867. Bruce, William Duff, Executive Engineer, Presidency Division, Calcutta, India.
1865. Bryant, Frederick William, Blackfriars Bridge Works, Chatham Place, London, E.C.

1866. Bryham, William, Rose Bridge and Douglas Bank Collieries, near Wigan.
1868. Buckton, George, Well House Foundry, Leeds.
1858. Burn, Henry, Midland Railway, Locomotive Department, Derby.
1856. Butler, Ambrose Edmund, Kirkstall Forge, Leeds.
1863. Butler, Arthur, Surdah, Radshye, Lower Bengal, India: (or care of W. J. Butler, Chipping Hill, Witham.)
1859. Butler, John, Stanningley Iron Works, near Leeds.
1859. Butler, John Octavius, Kirkstall Forge, Leeds.

1857. Cabry, Joseph, Resident Engineer, Blyth and Tyne Railway, Newcastle-on-Tyne.
1847. Cabry, Thomas, North Eastern Railway, York.
1847. Cammell, Charles, Cyclops Steel and Iron Works, Sheffield.
1867. Campbell, Daniel, 10 John Street, Adelphi, London, W.C.
1864. Campbell, David, 20 Castle Street, Liverpool.
1864. Campbell, James, Staveley Coal and Iron Works, Staveley, near Chesterfield.
1860. Cannell, Fleetwood James, Atlas Steel and Iron Works, Sheffield.
1860. Carbutt, Edward Hamer, Vulcan Iron Works, Thornton Road, Bradford, Yorkshire.
1865. Carlton, Samuel, Great Western Railway, Locomotive Department, Swindon.
1866. Carpmael, William, 24 Southampton Buildings, London, W.C.
1856. Carrett, William Elliott, Sun Foundry, Leeds.
1868. Carrington, Thomas, Jun., Mining Engineer, Kiveton Park Colliery, near Sheffield.
1864. Carrington, William Thomas, 10 Park Street, Westminster, S.W.
1858. Carson, James Irving, Locomotive Superintendent, West Hartlepool Harbour and Railway, Stockton-on-Tees.
1866. Chapman, Henry, 41 Boulevard Malesherbes, Paris.
1867. Chatwood, Samuel, Lancashire Safe and Lock Works, Bolton.
1857. Chrimes, Richard, Brass Works, Rotherham.
1866. Claridge, Thomas, Phœnix Foundry, near Bilston.
1859. Clark, George, Monkwearmouth Engine Works, Sunderland.
1867. Clark, George, Jun., Monkwearmouth Engine Works, Sunderland.
1862. Clark, James, Wellington Foundry, Leeds.
1867. Clark, William, Engineer to the Municipality of Calcutta, 9 Victoria Chambers, Victoria Street, Westminster, S.W.
1865. Clarke, John, Railway Foundry, Jack Lane, Leeds.
1859. Clay, William, Exchange Buildings, Liverpool.
1863. Clayton, Robert, Soho Foundry, Preston.
1866. Cleworth, Charles, Assistant Locomotive Superintendent, East Indian Railway, Jumalpore, India.
1867. Cliff, Joseph, Union Foundry, Bradford, Yorkshire.

1847. Clift, John Edward, Prospect Hill, Redditch.
1860. Clunes, Thomas, Worcester Engine Works, Worcester.
1858. Cochrane, Charles, Woodside Iron Works, near Dudley.
1860. Cochrane, Henry, Ormesby Iron Works, Middlesbrough.
1854. Cochrane, John, Woodside Iron Works, near Dudley.
1868. Cochrane, William, Mining Engineer, Elswick Colliery, Elswick, Newcastle-on-Tyne.
1867. Cockey, Francis Christopher, Selwood Iron Works, Frome.
1864. Coddington, William, Ordnance Cotton Mill, Blackburn.
1847. Coke, Richard George, Mining Engineer, Chesterfield.
1867. Coke, William Langton, 11 Great Queen Street, Westminster, S.W.
1864. Colburn, Zerah, 7 Gloucester Road, Regent's Park, London, N.W.
1853. Cooper, Samuel Thomas, Leeds Iron Works, Leeds.
1860. Cope, James, Mining Engineer, Pensnett, near Dudley.
1865. Corlett, Henry Lee, Great Southern and Western Railway, Carriage Department, Dublin.
1848. Corry, Edward, 8 New Broad Street, London, E.C.
1857. Cortazzi, Francis James, care of Hugh Hornby, Sandown, Wavertree, Liverpool.
1868. Coulson, William, Mining Engineer, Shamrock House, Durham.
1860. Coulthard, Hiram Craven, Park Iron Works, Blackburn.
1864. Cowans, John, St. Nicholas and Woodbank Iron Works, Carlisle.
1847. Cowper, Edward Alfred, 6 Great George Street, Westminster, S.W.
1862. Cox, Samuel H. F., Board of Health Office, Brynmawr, near Tredegar.
1847. Crampton, Thomas Russell, 12 Great George Street, Westminster, S.W.
1866. Craven, William, Vauxhall Iron Works, Osborne Street, Manchester.
1858. Crawhall, Joseph, St. Ann's Wire and Hemp Rope Works, Newcastle-on-Tyne.
1865. Cross, James, St. Helen's Locomotive Works, St. Helen's.
1863. Crow, George, Messrs. R. Stephenson and Co., Newcastle-on-Tyne.
1864. Crowe, Edward, Tees Side Iron Works, Middlesbrough.

1864. Daglish, George Heaton, St. Helen's Foundry, St. Helen's.
1866. Daniel, Edward Freer, Caerphilly Foundry, Cardiff.
1866. Daniel, William, 11 Blenheim Square, Leeds.
1865. Darby, Abraham, Ebbw Vale Iron Works, near Tredegar.
1864. Darby, Charles E., Brymbo Iron Works, near Wrexham.
1865. Davidson, James, Royal Arsenal, Laboratory Department, Woolwich, S.E.
1865. Davies, Benjamin, Huyton Bleach Works, near Chorley.
1868. Davis, Henry Wheeler, Resident Engineer, Great Eastern Railway, Stratford, London, E.
1863. Davy, Alfred, Park Iron Works, Sheffield.

1849. Dawes, George, Milton and Elsecar Iron Works, near Barnsley.
1860. Dawes, William Henry, Bromford Iron Works, Westbromwich.
1861. Dawson, Benjamin, South Hetton, near Fence Houses.
1868. Dean, William, Great Western Railway, Locomotive Department, Swindon.
1866. Death, Ephraim, Albert Works, Leicester.
1857. De Bergue, Charles, Strangeways Iron Works, Manchester.
1858. Dees, James, Whitehaven.
1858. Dempsey, William, 26 Great George Street, Westminster, S.W.
1868. Derham, John J., Machine Works, Pleasanton, near Blackburn.
1864. Dewhurst, John, Lancashire Steel Works, Gorton, Manchester.
1865. Dircks, Henry, 48 Charing Cross, London, S.W. (*Life Member.*)
1859. Dixon, John, Railway Foundry, Bradford, Yorkshire.
1865. Dobson, Benjamin, Messrs. Dobson and Barlow, Kay Street Works, Bolton.
1868. Dodman, Alfred, St. James's Works, Lynn.
1865. Domville, Charles Kelloch, Resident Engineer and Locomotive Superintendent, Belfast and County Down Railway, Belfast.
1865. Douglas, Charles P., Consett Iron Works, near Blackhill, County Durham.
1857. Douglas, George K., Messrs. R. Stephenson and Co., Newcastle-on-Tyne.
1857. Dove, George, St. Nicholas and Woodbank Iron Works, Carlisle.
1866. Downey, Alfred C., Ormesby Iron Works, Middlesbrough.
1847. Dübs, Henry, Glasgow Locomotive Works, Glasgow.
1857. Dunlop, John Macmillan, Holehird, Windermere.
1854. Dunn, Thomas, 52 Withington Street, Pendleton, Manchester.
1864. Dunn, Thomas Edward, care of Messrs. Bird and Co., Allahabad, India: (or care of R. Dunn, Howick, Bilton, Northumberland.)
1861. Dutton, Charles, Sams Lane, Westbromwich.
1860. Dyson, George, Tudhoe Iron Works, near Ferryhill.
1865. Dyson, Robert, Phœnix Wheel Tyre and Axle Works, Rotherham.

1859. Eassie, Peter Boyd, Railway Saw Mills, Gloucester.
1858. Easton, Edward, Grove Works, Southwark Street, London, S.E.
1867. Easton, James, Mining Engineer, Nest House, Gateshead.
1856. Eastwood, James, Railway Iron Works, Derby.
1868. Eddison, Robert William, Steam Plough and Locomotive Works, Leeds.
1866. Elce, John, Phœnix Iron Works, Jersey Street, Manchester.
1859. Elliot, George, M.P., Houghton-le-Spring, near Fence Houses.
1865. Elliot, Walter, Civil Engineer to the Colonial Government, Gibraltar.
1860. Elwell, Thomas, Messrs. Varrall Elwell & Poulot, 9 Avenue Trudaine, Paris.
1853. England, George, Hatcham Iron Works, London, S.E.
1861. Esson, William, Engineer, Cheltenham Gas Works, Cheltenham.
1864. Etienne, Antonin, 77 Calle de las Palmas, Seville, Spain.
1857. Evans, John Campbell, care of George W. Evans, 5 Wright Street, Hull.

1848. Everitt, George Allen, Kingston Metal Works, Adderley Street, Birmingham.
1864. Everitt, William Edward, Kingston Metal Works, Adderley Street, Birmingham.
1865. Evers, Frank, Cradley Iron Works, near Stourbridge.

1868. Fairbairn, Sir Andrew, Wellington Foundry, Leeds.
1857. Fairlie, Robert Francis, 9 Victoria Chambers, Victoria Street, Westminster, S.W.
1867. Fardon, Thomas, Linslade Iron Works, Leighton Buzzard.
1865. Faviell, Samuel Clough, Clarence Iron Works, Leeds.
1866. Fenby, Joseph Beverley, 61 Pershore Road, Edgbaston, Birmingham.
1854. Fernie, John, Clarence Iron Works, Leeds.
1866. Fiddes, Walter, Engineer, Bristol United Gas Works, Bristol.
1867. Field, Edward, Chandos Chambers, Buckingham Street, Adelphi, London, W.C.
1861. Field, Joshua, 110 Westminster Bridge Road, Lambeth, London, S.E.
1865. Filliter, Edward, Resident Engineer, Leeds Water Works, 16 East Parade, Leeds.
1868. Firth, Arthur, Leeds Iron Works, Leeds.
1868. Firth, Samuel, 14 Springfield Mount, Leeds.
1864. Fleet, Thomas, Crown Boiler Works, Westbromwich.
1861. Fleetwood, Daniel Joseph, 58 Broad Street, Birmingham.
1847. Fletcher, Edward, Locomotive Superintendent, North Eastern Railway, Gateshead.
1858. Fletcher, Henry Allason, Lowca Engine Works, Whitehaven. (*Life Member.*)
1857. Fletcher, James, Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.
1866. Fletcher, James, Jun., Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.
1867. Fletcher, Lavington Evans, Association for the Prevention of Steam Boiler Explosions, 41 Corporation Street, Manchester.
1859. Fogg, Robert, 17 Park Street, Westminster, S.W.
1861. Forster, Edward, Spon Lane Glass Works, near Birmingham.
1868. Forster, John, Messrs. Westray and Forster, Barrow-in-Furness, Lancashire.
1849. Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
1864. Foster, Edward Henry, Lecourt, Petersfield.
1861. Foster, Sampson Lloyd, Old Park Hall, Walsall.
1847. Fothergill, Benjamin, 139 Cannon Street, London, E.C.
1866. Fowler, George, Hucknall Torkard Collieries, near Nottingham.

1847. Fowler, John, 2 Queen Square Place, Westminster, S.W.
1847. Fox, Sir Charles, 8 New Street, Spring Gardens, London, S.W.
1866. Fox, Charles Douglas, 8 New Street, Spring Gardens, London, S.W.
1859. Fraser, John, 18 York Place, Leeds.
1866. Fraser, John Simpson, Carriage and Wagon Superintendent, Great Western Railway, Paddington, London, W.
1856. Freeman, Joseph, 98 Cannon Street, London, E.C.
1864. Frost, Thomas, Wadsley Bridge Iron and Steel Works, near Sheffield.
1852. Froude, William, Elmsleigh, Paignton, South Devon.
1866. Fry, Albert, Bristol Wagon Works, Temple Gate, Bristol.

1865. Gainsford, William Dunn, Sheffield Coal Co., Sheffield.
1866. Galloway, Charles John, Knott Mill Iron Works, Manchester.
1862. Galton, Capt. Douglas, R.E., War Office, Pall Mall, London, S.W.
1847. Garland, William S., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1867. Gauntlett, William Henry, Middlesbrough.
1848. Gibbons, Benjamin, The Leasowes, near Birmingham.
1856. Gilkes, Edgar, Tees Engine Works, Middlesbrough.
1866. Gilroy, George, Engineer, Ince Hall Colliery, Wigan.
1862. Godfrey, Samuel, Messrs. Bolckow and Vaughan's Iron Works, Middlesbrough.
1867. Gooch, William Frederick, Vulcan Foundry, Warrington.
1865. Göransson, Göran Fredrick, Steel Works, Gefle and Hägbo, Sweden.
1865. Gray, John McFarlane, Board of Trade Steam Ship Surveyor, Custom House, Dublin.
1861. Green, Edward, Jun., Phœnix Works, Wakefield.
1867. Greenwell, George Clementson, Mining Engineer, Poynton, near Stockport.
1858. Greenwood, Thomas, Albion Works, Armley Road, Leeds.
1857. Gregory, John, 57 Millbank Street, Westminster, S.W.
1865. Greig, David, Steam Plough and Locomotive Works, Leeds.
1866. Grice, Edwin James, Stour Valley Works, Spon Lane, Westbromwich.
1860. Grice, Frederic Groom, Cwmbran Nut and Bolt Works, near Newport, Monmouthshire.
1868. Grierson, Henry Houldsworth, St. George's Iron Works, Hulme, Manchester.
1866. Gurden, Charles Frederick, Superintendent Engineer, Brazil and River Plate Steam Boat Co., 43 Canning Street, Birkenhead.

1863. Hackney, William, 3 Great George Street, Westminster, S.W.
1861. Haggie, Peter, Hemp and Wire Rope Works, Gateshead.
1863. Hall, Joseph, Gratz Iron Works, Gratz, Styria, Austria.

1857. Hall, William, 167 Dartmouth Street, Birmingham.
1860. Hamilton, Gilbert, Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1858. Harding, John, Beeston Manor Iron Works, Leeds.
1859. Harman, Henry William, Canal Street Works, Manchester.
1856. Harrison, George, Canada Works, Birkenhead.
1858. Harrison, Thomas Elliot, 1 Westminster Chambers, Victoria Street, Westminster, S.W.
1865. Harrison, William, Bank Foundry, Blackburn.
1865. Harrison, William Arthur, Cambridge Street Works, Manchester.
1858. Haswell, John A., North Eastern Railway, Locomotive Department, Gateshead.
1857. Haughton, S. Wilfred, Greenbank, Carlow. (*Life Member.*)
1861. Hawkins, William Bailey, 2 Suffolk Lane, Cannon Street, London, E.C.
1856. Hawksley, Thomas, 30 Great George Street, Westminster, S.W.
1848. Hawthorn, William, Messrs. Hawthorn and Co., Newcastle-on-Tyne.
1862. Haynes, Thomas John, Calpe Foundry, North Front, Gibraltar.
1860. Head, John, Messrs. Ransomes and Sims, Orwell Works, Ipswich.
1853. Headly, James Ind, Eagle Foundry, Mill Road, Cambridge.
1857. Healey, Edward Charles, 163 Strand, London, W.C.
1862. Heath, William J. W., Soane Irrigation Works, Baroon, Dehree on Soane, Grand Trunk Road, Shahabad, India: (or care of John J. Heath, 67 Great Charles Street, Birmingham.)
1864. Heathfield, Richard, Lion Galvanising Works, Birmingham Heath, Birmingham.
1860. Heaton, George, Royal Copper Mint, Icknield Street East, Birmingham.
1868. Heaton, John, Langley Mill Steel and Iron Works, near Nottingham.
1865. Hetherington, John Muir, Vulcan Works, Pollard Street, Manchester.
1866. Hetherington, Thomas Ridley, Vulcan Works, Pollard Street, Manchester.
1864. Hetherington, William Isaac, Vulcan Works, Pollard Street, Manchester.
1865. Hewett, Edward Edwards, Yorkshire Engine Co., Meadow Hall Works, near Sheffield.
1866. Hickman, George Haden, Groveland Iron Works, Dudley Port, Tipton.
1864. Hide, Thomas C., 46 Fenchurch Street, London, E.C.
1863. Hind, Roger, Scotland Bank Iron Works, Warrington.
1866. Hodgson, Charles, 163 Strand, London, W.C.
1858. Hodgson, Robert, North Eastern Railway, Newcastle-on-Tyne.
1852. Holcroft, James, Norton, near Stourbridge.
1866. Holcroft, Thomas, Bilston Foundry, Bilston.
1865. Holliday, John, Messrs. Bethell's Creosote Works, Westbromwich.
1863. Holt, Francis, Gorton Foundry, Manchester.
1867. Holt, William Lyster, 6 Storey's Gate, Westminster, S.W.

1867. Homer, Charles James, Mining Engineer, Chatterley Ironstone Works, Tunstall, near Stoke-upon-Trent.
1848. Homersham, Samuel Collett, 19 Buckingham Street, Adelphi, London, W.C.
1860. Hopkins, James Innes, 95 Cannon Street, London, E.C.
1866. Hopkins, John Satchell, Tinplate Works, Granville Street, Birmingham.
1856. Hopkinson, John, London Road Iron Works, Manchester.
1867. Hopper, William, Machine Works, Moscow, Russia.
1867. Horrocks, Samuel, 51 King Street, Manchester.
1868. Horsley, Thomas, Jun., Alfreton Iron Works, Alfreton.
1858. Horsley, William, Jun., Whitehill Point Iron Works, Percy Main, near Newcastle-on-Tyne.
1868. Horton, Enoch, Alma Works, Darlaston, near Wednesbury.
1851. Horton, Joshua, Ætna Works, Smethwick, near Birmingham.
1867. Horton, Thomas Ellwood, Lilleshall Iron Works, Oakengates, near Wellington, Shropshire.
1858. Hosking, John, Gateshead Iron Works, Gateshead.
1866. Houghton, John Campbell Arthur, Woodside Iron Works, near Dudley.
1864. Howard, Eliot, 84 Upper Whitecross Street, London, E.C.
1860. Howard, James, M.P., Britannia Iron Works, Bedford.
1867. Howard, Robert Luke, 84 Upper Whitecross Street, London, E.C.
1860. Howe, William, Clay Cross Coal and Iron Works, near Chesterfield.
1861. Howell, Joseph Bennett, Hartford Steel Works, Sheffield.
1866. Hoyle, William Jennings, Messrs. Whitworth and Co., Chorlton Street, Manchester.
1868. Hudswell, William Shillito, Railway Foundry, Jack Lane, Leeds.
1867. Hughes, George Douglas, Queen's Foundry, London Road, Nottingham.
1864. Hulse, William Wilson, Whalley Chambers, 88 King Street, Manchester.
1859. Hunt, James P., Corngreaves Iron Works, near Birmingham.
1856. Hunt, Thomas, care of the Secretary, Westminster Palace Hotel, London, S.W.
1864. Hutchinson, Edward, Skerne Iron Works, Darlington.
1863. Hutton, Walter Stuart, Prospect Works, Hunslet Lane, Leeds.
1865. Hyde, Lt.-Colonel Henry, R.E., Master of the Mint, Calcutta, India: (or care of Rev. H. M. C. Hyde, 14 Grove Lane, Camberwell, London, S.E.) (*Life Member.*)

1867. Inglis, William, Soho Iron Works, Bolton.
1866. Ireland, William, 41 Beech Lane, Macclesfield.

1865. Jackson, John, Stibbington House, Wansford.
1859. Jackson, Matthew Murray, Engineer-in-Chief, Imperial Danube Steam Navigation Works, Pesth, Austria.

1847. Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
1861. Jackson, Robert, Ætna Steel Works, Sheffield.
1860. Jackson, Samuel, Cyclops Steel and Iron Works, Sheffield.
1866. Jaeger, Herrmann Frederic, Gorton Foundry, Manchester.
1858. Jaffrey, George William, Hartlepool Iron Works, Hartlepool.
1856. James, Jabez, 40 Prince's Street, Commercial Road, Lambeth, London, S.E.
1868. James, John, Ebbw Vale Iron Works, near Tredegar.
1861. Jeffcock, Thomas William, Mining Engineer, 18 Bank Street, Sheffield.
1863. Jeffreys, Edward A., Low Moor Iron Works, near Bradford, Yorkshire.
1861. Jessop, Thomas, Park Steel Works, Sheffield.
1854. Jobson, John, Derwent Foundry, Derby.
1868. Jobson, Robert, Phœnix Works, Dudley.
1863. Johnson, Bryan, Flookersbrook Foundry, Chester.
1847. Johnson, James, North Staffordshire Railway, Engineer's Office, Stoke-upon-Trent.
1861. Johnson, Samuel Waite, Locomotive Superintendent, Great Eastern Railway, Stratford, London, E.
1847. Jones, Edward, The Larches, Handsworth, near Birmingham.
1857. Jones, Hodgson, 67 Victoria Street, Westminster, S.W.

1857. Kay, James Clarkson, Phœnix Foundry, Bury, Lancashire.
1867. Kellett, John, 2 Newsbams Buildings, King Street, Wigan.
1857. Kendall, William, Locomotive Superintendent, Blyth and Tyne Railway, Percy Main, near Newcastle-on-Tyne.
1863. Kennan, James, Agricultural Implement Works, 19 Fishamble Street, Dublin.
1847. Kennedy, James, Cressington Park, Aigburth, Liverpool.
1857. Kennedy, Lt.-Colonel John Pitt, Engineer, Bombay Baroda and Central Indian Railway; 45 Finsbury Circus, London, E.C.
1863. Kennedy, John Pitt, Bombay Baroda and Central Indian Railway; 45 Finsbury Circus, London, E.C.
1868. Kennedy, Thomas Stuart, Wellington Foundry, Leeds.
1868. Kerr, Peter, Thread Works, New Street, Paisley.
1866. Kershaw, John, 24 Duke Street, Westminster, S.W.
1867. Kimball, Frederick James, 35 South Third Street, Philadelphia, Pennsylvania, United States.
1865. Kirkaldy, David, Testing and Experimental Works, The Grove, Southwark Street, London, S.E.
1847. Kirtley, Matthew, Locomotive Superintendent, Midland Railway, Derby.
1864. Kirtley, William, Midland Railway, Locomotive Department, Derby.
1859. Kitson, Frederick William, Monkbridge Iron Works, Leeds.
1848. Kitson, James, Airedale Foundry, Leeds.

1859. Kitson, James, Jun., Monkbridge Iron Works, Leeds.
1868. Kitson, John Hawthorn, Airedale Foundry, Leeds.
1866. Knap, Conrad, Star Tube Works, Heneage Street, Birmingham.
1863. Knight, Thomas, 130 Bradford Street, Birmingham.

1866. Lambert, William Blake, Berwick-upon-Tweed.
1867. Lancaster, Charles William, Gun Manufactory, 151 New Bond Street, London, W.
1863. Lancaster, John, M.P., Kirkless Hall Coal and Iron Works, near Wigan.
1860. Law, David, Phœnix Iron Works, Glasgow.
1867. Lawrence, Henry, The Grange Iron Works, Durham.
1857. Laybourn, John, Isca Foundry, Newport, Monmouthshire.
1856. Laybourn, Richard, Rhymney Iron Works, Tredegar.
1860. Lea, Henry, 35 Paradise Street, Birmingham.
1868. Lea, John, Bowling Iron Works, near Bradford, Yorkshire.
1865. Ledger, Joseph, West Cumberland Hæmatite Iron Works, Workington.
1862. Lee, J. C. Frank, 22 Great George Street, Westminster, S.W.
1863. Lees, Samuel, Jun., Park Bridge Iron Works, Ashton-under-Lyne.
1863. Leigh, Evan, Junction Works, Miles Platting, Manchester.
1865. Leigh, Frederick Allen, Junction Works, Miles Platting, Manchester.
1866. Leigh, Joseph D., Ellesmere Foundry, Patricroft, near Manchester.
1858. Leslie, Andrew, Iron Ship Building Yard, Hebburn Quay, Gateshead.
1860. Lewis, Thomas William, Abercanaid House, Merthyr Tydvil.
1864. Lindsley, George, Great Western Railway, Locomotive Department, Swindon.
1856. Linn, Alexander Grainger, 2 Queen Square Place, Westminster, S.W.
1857. Little, Charles, Staveley Coal and Iron Works, Staveley, near Chesterfield.
1866. Little, George, Hartford Iron Works, Oldham.
1867. Livesey, James, 9 Victoria Chambers, Victoria Street, Westminster, S.W.
1867. Lloyd, Charles, 6 Westminster Chambers, Victoria Street, Westminster, S.W.
1863. Lloyd, Edward R., Albion Tube Works, Nile Street, Birmingham.
1854. Lloyd, George Braithwaite, Messrs. Lloyds, High Street, Birmingham. (*Life Member.*)
1862. Lloyd, John, Lilleshall Iron Works, Oakengates, near Wellington, Shropshire.
1866. Lloyd, Joseph Foster, Darlaston Green Iron and Steel Works, near Wednesbury.
1847. Lloyd, Sampson, Old Park Iron Works, Wednesbury.
1864. Lloyd, Sampson Zachary, Old Park Iron Works, Wednesbury.
1852. Lloyd, Samuel, Old Park Iron Works, Wednesbury.
1862. Lloyd, Wilson, Moor Hall, Sutton Coldfield, near Birmingham.
1863. Loam, Matthew Hill, Engineer, Gas and Water Works, Nottingham.

1856. Longridge, Robert Bewick, Steam Boiler Assurance Company, 67 King Street, Manchester.
1865. Longridge, William Smith, Alderwasley Iron Works, Ambergate, near Derby.
1866. Lord, Edward, Canal Street Works, Todmorden.
1859. Lord, Thomas Wilks, Bank Mills, Leeds.
1861. Low, George, St. Peter's Iron Works, Ipswich.
1865. Lundh, Sverier Hakon, 8 Lille Strandgade, Christiania, Norway: (or 9B New Broad Street, London, E.C.)
1854. Lynde, James Gascoigne, Town Hall, Manchester.
1868. Lyndon, George Frederick, Minerva Works, Fazeley Street, Birmingham.

1864. Macfarlane, Walter, Saracen Foundry, Glasgow.
1856. Mackay, John, Mount Hermon, Drogheda.
1864. Macnab, Archibald Francis, Peninsular and Oriental Steam Navigation Co., Hong-Kong, China: (or care of P. and O. S. N. Co., 122 Leadenhall Street, London, E.C.)
1865. MacNay, William, Shildon Engine Works, Darlington.
1865. Macnee, Daniel, Brinsworth Iron and Steel Works, Rotherham.
1867. Mallet, Robert, 7 Westminster Chambers, Victoria Street, Westminster, S.W.
1859. Manning, John, Boyne Engine Works, Hunslet, Leeds.
1862. Mansell, Richard Christopher, South Eastern Railway, Carriage Department, Ashford.
1862. Mappin, Frederick Thorpe, Sheaf Works, Sheffield.
1857. March, George, Union Foundry, Dewsbury Road, Leeds.
1856. Markham, Charles, Staveley Coal and Iron Works, Staveley, near Chesterfield.
1865. Marshall, Francis Carr, Jarrow Engine Works, Quayside, Newcastle-on-Tyne.
1862. Marshall, James, North Eastern Railway, Carlisle.
1859. Marshall, William Ebenezer, Sun Foundry, Leeds.
1847. Marshall, William Prime, 81 Newhall Street, Birmingham.
1859. Marten, Edward Bindon, Engineer, Stourbridge Water Works, 56 Hagley Street, Stourbridge.
1853. Marten, Henry John, Parkfield Iron Works, near Wolverhampton.
1867. Martin, William, Messrs. W. Martin Fils et Cie., 43 Rue d'Elbeuf, Rouen, France.
1857. Martindale, Lt.-Colonel Ben Hay, R.E., Controller, Montreal, Canada.
1854. Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
1864. Martley, William, Locomotive Superintendent, London Chatham and Dover Railway, Longhedge Works, Wandsworth Road, London, S.W.
1857. Masselin, Armand, 14 Rue de Lancry, Paris.

1867. Mather, William, Salford Iron Works, Manchester.
1853. Mathews, William, North Grove, Great Malvern.
1848. Matthew, John, 13 Park Street, Park Lane, London, W.
1847. Matthews, William Anthony, Sheaf Works, Sheffield.
1853. Maudslay, Henry, Bystock, near Exmouth. (*Life Member.*)
1864. Maudslay, Thomas Henry, 110 Westminster Bridge Road, Lambeth, London, S.E.
1861. May, Robert Charles, 6 Great George Street, Westminster, S.W.
1857. May, Walter, Suffolk Works, Berkley Street, Birmingham.
1865. Maylor, John, 11 Commerce Chambers, Lord Street, Liverpool.
1859. Maylor, William, Calicut, Madras, India.
1847. McClean, John Robinson, M.P., 23 Great George Street, Westminster, S.W.
1865. McDonnell, Alexander, Locomotive Superintendent, Great Southern and Western Railway, Dublin.
1867. McEwen, James, Wordsley Foundry, Stourbridge.
1864. McEwen, Lawrence Thompson, Glaisdale Iron Works, near Yarm.
1868. McKay, Benjamin, Small Arms Factory, Small Heath, near Birmingham.
1860. McKenzie, James, Well House Foundry, Leeds.
1859. McKenzie, John, Worcester Engine Works, Worcester.
1863. Meek, Sturges, Resident Engineer, Lancashire and Yorkshire Railway, Manchester.
1858. Meik, Thomas, Engineer to the River Wear Commissioners, Sunderland.
1857. Menelaus, William, Dowlais Iron Works, Merthyr Tydvil.
1866. Meredith, Alban, 96 Newgate Street, London, E.C.
1867. Merryweather, Richard M., 63 Long Acre, London, W.C.
1857. Metford, William Ellis, Flook House, Taunton.
1847. Middleton, William, Vulcan Iron Foundry, Summer Lane, Birmingham.
1862. Miers, Francis C., Stoneleigh Lodge, Grove Road, Clapham Park, London, S.W.
1864. Miers, John William, 74 Addison Road, Kensington, London, W.
1862. Millward, John, 27 Paradise Street, Birmingham.
1856. Mitchell, Charles, The Grange, Surbiton Hill, Kingston-on-Thames.
1861. Mitchell, Joseph, Worsbrough Dale Colliery, near Barnsley.
1859. Moor, William, Engineer, Hetton Colliery, Hetton, near Fence Houses.
1864. Moore, Sampson, North Foundry, Cotton Street, Clarence Dock, Liverpool.
1864. Morgan, Joshua Llewelyn, Kingscombe, near Cowbridge.
1867. Morgans, Thomas, Foundry and Wagon Works, Pontypool.
1868. Morris, William, Waldridge Colliery, Chester-le-Street, near Fence Houses.
1849. Morrison, Robert, Brotton Grange, Saltburn-by-the-Sea, Yorkshire.
1865. Morton, Robert, Alliance Chambers, Borough, London, S.E.
1865. Mosse, James Robert, Mauritius Railways, Port Louis, Mauritius.
1858. Mountain, Charles George, Suffolk Works, Berkley Street, Birmingham.

1866. Muir, Andrew, Victoria Bridge Works, Salford, Manchester.
1863. Muir, William, 57 Claverton Street, Pimlico, London, S.W.
1865. Murdock, William Mallabey, Barrow Hæmatite Steel Works, Barrow-in-Furness, Lancashire.
1859. Murphy, James, Railway Works, Newport, Monmouthshire.
1858. Murray, Thomas H., Engine Works, Chester-le-Street, near Fence Houses.
1863. Musgrave, John, Jun., Globe Iron Works, Bolton.

1848. Napier, John, Vulcan Foundry, Glasgow.
1867. Napier, John D., Kilmun House, Holt Hill, Birkenhead.
1856. Napier, Robert, West Shandon, Helensburgh, near Glasgow. (*Life Member.*)
1861. Naylor, John William, Wellington Foundry, Leeds.
1858. Naylor, William, Great Indian Peninsula Railway, 3 New Broad Street, London, E.C.
1863. Neilson, Walter Montgomerie, Hyde Park Locomotive Works, Glasgow.
1860. Nettlefold, Joseph Henry, Screw Works, Broad Street, Birmingham.
1866. Newdigate, Albert Lewis, Byrkley Lodge, near Burton-on-Trent.
1862. Newton, William Edward, 66 Chancery Lane, London, W.C.
1858. Nichol, Peter Dale, care of Anthony Nichol, 19 Quay, Newcastle-on-Tyne.
1866. Norfolk, Richard, Beverley Iron and Wagon Works, Beverley.
1850. Norris, Richard Stuart, 272 Upper Parliament Street, Liverpool.
1868. Norris, William Gregory, Coalbrookdale Iron Works, near Wellington, Shropshire.

1868. O'Connor, Charles, Newark Foundry, Bath.
1866. Oliver, William, Victoria Foundry, Chesterfield.
1867. Olrick, Lewis, 27 Leadenhall Street, London, E.C.
1864. Ommanney, Frederick Francis, New Bridge Foundry, Adelphi Street, Salford, Manchester.
1867. Oughterson, George Blake, Messrs. W. Martin Fils et Cie., 43 Rue d'Elbeuf, Rouen, France.
1847. Owen, William, Phœnix Wheel Tyre and Axle Works, Rotherham.

1868. Paget, Arthur, Machine Works, Loughborough.
1868. Parker, Frederick, Steam Plough and Locomotive Works, Leeds.
1868. Parker, Henry, 20 Mecklenburgh Square, Gray's Inn Road, London, W.C.
1865. Parkes, Alexander, Stephenson Metal Tube Works, Liverpool Street, Birmingham.
1866. Parton, Thomas, Rough Hay Iron Works, Darlaston, near Wednesbury.
1847. Peacock, Richard, Messrs. Beyer Peacock and Co., Gorton Foundry, Manchester.

1867. Pearce, Robert Webb, Carriage Superintendent, East Indian Railway, Calcutta, India.
1848. Pearson, John, 7 Old Hall Street, Liverpool.
1866. Peel, George, Jun., Soho Iron Works, Pollard Street, Manchester.
1866. Peele, Arthur John, 90 Queen Street, London, E.C.
1848. Penn, John, The Cedars, Lee, London, S.E. (*Life Member.*)
1861. Perkins, Loftus, 6 Seaford Street, Regent Square, London, W.C.
1866. Perks, John Hartley, Shrubbery Iron Works, Wolverhampton.
1856. Perring, John Shae, 104 King Street, Manchester.
1863. Perry, Thomas J., Highfields Engine Works, Bilston.
1865. Perry, William, Messrs. Samuel Perry and Sons, Wednesbury.
1860. Peyton, Edward, Bordesley Works, Birmingham.
1867. Pidgeon, Daniel, Britannia Iron Works, Banbury.
1856. Piggott, George, Birmingham Heath Boiler Works, Birmingham.
1854. Pilkington, Richard, Jun., Wolsingham, near Darlington.
1859. Pitts, Joseph, Stanningley Iron Works, near Leeds.
1859. Platt, John, M.P., Hartford Iron Works, Oldham.
1867. Platt, Samuel Radcliffe, Hartford Iron Works, Oldham.
1862. Player, John, 3904 Walnut Street, Philadelphia, Pennsylvania, United States: (or care of William J. Player, Longford Court, Neath.)
1866. Plum, Thomas Edward Day, Atlas Works, Manchester.
1861. Plum, Thomas William, Old Park Iron Works, near Shiffnal.
1860. Ponsonby, Edward Vincent, Parker Place, Broomhill, Sheffield.
1866. Porter, Charles Talbot, 102 Broadway, New York, United States.
1861. Porter, Robert, 47 Paradise Street, Birmingham.
1864. Potts, Benjamin Langford Foster, 200 Camberwell Grove, London, S.E.
1851. Potts, John Thorpe, 200 Camberwell Grove, London, S.E.
1867. Powell, William, Harbour Works, Port Erin, Isle of Man.
1867. Pratchitt, John, Denton Iron Works, Carlisle.
1865. Pratchitt, William, Denton Iron Works, Carlisle.
1856. Preston, Francis, Ancoats Bridge Works, Ardwick, Manchester.
1866. Price, John, Chief Surveyor, Underwriters' Registry for Iron Vessels, 42 Villiers Street, Sunderland.
1866. Putnam, William, Darlington Forge, Darlington.

1868. Rafarel, Frederic William, Cwmbran Nut and Bolt Works, near Newport, Monmouthshire.
1862. Rake, Alfred Stansfield, Bank Buildings, Newcastle-on-Tyne.
1864. Ramage, Robert, Locomotive Superintendent, Midland Great Western Railway, Dublin.
1847. Ramsbottom, John, Locomotive Superintendent, London and North Western Railway, Crewe.

1866. Ramsden, James, Abbot's Wood, Barrow-in-Furness, Lancashire.
1860. Ransome, Allen, Jun., Messrs. Worssam and Co., King's Road, Chelsea, London, S.W.
1862. Ransome, Robert James, Orwell Works, Ipswich.
1867. Ratcliff, Daniel Rowlinson, Phœnix Safe Works, Liverpool.
1867. Ratliffe, George, London and North Western Railway, Locomotive Department, Crewe.
1862. Ravenhill, John R., Glass House Fields, Ratcliff, London, E.
1859. Rennie, George Banks, 20 Lowndes Street, Lowndes Square, London, S.W.
1862. Reynolds, Edward, Don Steel Works, Sheffield.
1866. Reynolds, Frederic Cornell, 37 Great George Street, Westminster, S.W.
1866. Richards, Edward Windsor, Ebbw Vale Iron Works, near Tredegar.
1863. Richards, Edwin, Tredegar Iron Works, Tredegar.
1865. Richards, Job, Parkgate Iron Works, Rotherham.
1856. Richards, Josiah, Abersychan Iron Works, Pontypool.
1863. Richardson, Edward, Lyttelton and Christchurch Railway, Christchurch, New Zealand.
1865. Richardson, John, Methley, near Leeds.
1858. Richardson, Thomas, Hartlepool Iron Works, Hartlepool.
1859. Richardson, William, Hartford Iron Works, Oldham.
1865. Rideal, Samuel, 18 Hopwood Avenue, Manchester.
1863. Rigby, Samuel, Cock Hedge Mill, Warrington.
1848. Robertson, Henry, Great Western Railway, Shrewsbury.
1865. Robey, Robert, Perseverance Iron Works, Lincoln.
1859. Robinson, John, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1865. Robinson, John, Railway Works, Rochdale.
1866. Robson, Thomas, Mining Engineer, Lumley Colliery, Fence Houses.
1868. Rogers, William, Resident Engineer, Port Wakefield and Hoyles Plains Railway, Port Wakefield, near Adelaide, South Australia.
1853. Ronayne, Joseph P., 4 Harbour Hill, Queenstown.
1867. Rose, Henry Fullwood, Albert Iron Works, Moxley, near Wednesbury.
1866. Rose, Thomas, Bradley Iron Works, near Bilston.
1867. Rose, Thomas, Machine Works, 37 Victoria Street, Manchester.
1866. Rosthorn, Joseph De, Messrs. Rosthorn Brothers, Vienna.
1856. Rouse, Frederick, Great Northern Railway, Locomotive Department, Boston.
1857. Routledge, William, New Bridge Foundry, Adelphi Street, Salford, Manchester.
1860. Rumble, Thomas William, 6A Victoria Street, Westminster, S.W. (*Life Member.*)
1847. Russell, John Scott, 5 Westminster Chambers, Victoria Street, Westminster, S.W.
1867. Ruston, Joseph, Sheaf Iron Works, Lincoln.

1866. Sacré, Alfred, Yorkshire Engine Co., Meadow Hall Works, near Sheffield.
1859. Sacré, Charles, Locomotive Superintendent, Manchester Sheffield and Lincolnshire Railway, Gorton, near Manchester.
1868. Sacré, Edward Antoine, 26 Parliament Street, Westminster, S.W.
1867. Sadoine, Eugène, Société Cockerill, Seraing, Belgium.
1864. Said, Colonel M., Bey, Engineer, Turkish Service, Constantinople: (or care of J. C. Frank Lee, 22 Great George Street, Westminster, S.W.)
1859. Salt, George, Saltaire, near Bradford, Yorkshire.
1864. Samuda, Joseph D'Aguilar, M.P., Iron Ship Building Yard, Isle of Dogs, Poplar, London, E.
1848. Samuel, James, 26 Great George Street, Westminster, S.W.
1857. Samuelson, Alexander, 27 Cornhill, London, E.C.
1865. Samuelson, Bernhard, M.P., Britannia Iron Works, Banbury.
1857. Samuelson, Martin, Engine Works, Neptune Street, Hull.
1865. Sandberg, Christer Peter, Engineer, Swedish Government Railway Service, Stockholm, Sweden: (or care of Messrs. Tottie and Sons, 2 Alderman's Walk, Bishopsgate Street, London, E.C.)
1861. Sanderson, George Grant, Tudhoe Iron Works, near Ferryhill.
1864. Sanderson, John, Flosh View, Wigton.
1860. Schneider, Henry William, Ulverstone Hæmatite Iron Works, Barrow-in-Furness, Lancashire.
1866. Scholtze, Aleksander, Messrs. Scholtze Brothers, Engineers and Boiler Makers, Warsaw, Poland.
1865. Scott, Edward, 10 Tib Lane, Cross Street, Manchester.
1868. Scott, George Lamb, 29 Greenhill Street, Greenheys, Manchester.
1861. Scott, Walter Henry, Locomotive and Carriage Superintendent, Mauritius Railways, Port Louis, Mauritius: (or care of Joseph Reid, 3 Alexandra Terrace, Stanstead Road, Forest Hill, London, S.E.)
1868. Scriven, Charles, Leeds Old Foundry, Marsh Lane, Leeds.
1864. Seddon, John, Wallgate, Wigan.
1857. Selby, George Thomas, Smethwick Tube Works, Birmingham.
1867. Selby, Millin, Teakova Cotton Mill, near Ivanova, Vladimir, Russia: (or care of Millin Selby, Sen., Atherton Hall, Leigh, near Manchester.)
1865. Sellers, William, Pennsylvania Avenue, Philadelphia, Pennsylvania, United States.
1850. Shanks, Andrew, 6 Robert Street, Adelphi, London, W.C.
1863. Sharp, Henry, Bolton Iron and Steel Works, Bolton.
1867. Sharpe, Charles James, 17B Great George Street, Westminster, S.W.
1862. Sharpe, William John, 17B Great George Street, Westminster, S.W.
1864. Shaw, Duncan, Mining Engineer, Cordova, Spain.
1856. Shelley, Charles Percy Bysshe, 113 Victoria Street, Westminster, S.W.
1861. Shepherd, John, Union Foundry, Hunslet Road, Leeds.

1859. Shuttleworth, Joseph, Stamp End Iron Works, Lincoln.
1851. Siemens, Charles William, 3 Great George Street, Westminster, S.W.
1862. Silvester, John, Messrs. George Salter and Co., Spring Balance Works, Westbromwich.
1847. Sinclair, Robert, Great Eastern Railway, Stratford, London, E.
1857. Sinclair, Robert Cooper, Hartshill, near Atherstone.
1859. Slater, Isaac, Gloucester Wagon Works, Gloucester.
1853. Slaughter, Edward, Avonside Engine Works, Bristol.
1866. Smethurst, Joseph, Guide Bridge Iron Works, Audenshaw, near Manchester.
1866. Smith, Edward Fisher, Coneygre Iron Works, Dudley Port, Dudley.
1866. Smith, Fereday, Bridgewater Offices, Manchester.
1860. Smith, Henry, Brierley Hill Iron Works, Brierley Hill.
1858. Smith, Isaac, 36 Lancaster Street, Birmingham.
1860. Smith, John, Brass Foundry, Traffic Street, Derby.
1857. Smith, Josiah Timmis, Ulverstone Hæmatite Iron Works, Barrow-in-Furness, Lancashire.
1859. Smith, Matthew, Caledonia Wire Mills, Halifax.
1857. Smith, William, 19 Salisbury Street, Adelphi, London, W.C.
1866. Smith, William, Eglinton Engine Works, Glasgow.
1863. Smith, William Ford, Gresley Iron Works, Ordsal Lane, Salford, Manchester.
1857. Snowdon, Thomas, 147 High Street, Stockton-on-Tees.
1859. Sokoloff, Colonel Alexander, Engineer, Russian Imperial Service, Steam Marine Department, Cronstadt, Russia : (or care of Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.)
1863. Somerville, Wallace Cochrane, London Works, Birmingham.
1858. Sörensen, Bergerius, Engineer-in-Chief, Royal Norwegian Navy Department, Horten Dockyard, Norway : (or care of Messrs. Tottie and Sons, 2 Alderman's Walk, Bishopsgate Street, London, E.C.)
1865. Sparrow, Arthur, Lane End Iron Works, Longton, near Stoke-upon-Trent.
1865. Sparrow, William Mander, Osier Bed Iron Works, Wolverhampton.
1866. Spencer, Eli, Hartford Iron Works, Oldham.
1859. Spencer, John Frederick, Oakhill, near Bath.
1867. Spencer, John W., Newburn Steel Works, Newcastle-on-Tyne.
1853. Spencer, Thomas, Clough Hall Iron Works, Kidsgrove, near Stoke-upon-Trent.
1854. Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.
1864. Spittle, Thomas, Cambrian Iron Foundry, Newport, Monmouthshire.
1862. Stableford, William, Oldbury Carriage Works, near Birmingham.
1868. Stenson, William Towndrow, Whitwick Colliery, Coalville, near Leicester.
1866. Stephens, John Classon, Blackhall Place Iron Works, Dublin.

1868. Stephenson, George Robert, 24 Great George Street, Westminster, S.W.
1866. Stevenson, John, Acklam Iron Works, Middlesbrough.
1867. Stevenson, Robert, Mining Engineer, Clay Cross, near Chesterfield.
1859. Stewart, Charles P., Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1851. Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London, E.
1867. Stirling, Patrick, Locomotive Superintendent, Great Northern Railway, Doncaster.
1864. Stokes, James Folliott, 21 Parliament Street, Westminster, S.W.
1863. Storey, John Henry, Knott Mill Brass and Copper Works, Little Peter Street, Manchester.
1862. Strong, Joseph F., Resident Engineer, East Indian Railway, Cawnpore, India.
1865. Stroudley, William, Locomotive Superintendent, Highland Railway, Inverness.
1861. Sumner, William, 2 Brazenose Street, Manchester.
1860. Swindell, James Evers, Parkhead Iron Works, Dudley.
1864. Swindell, James Swindell Evers, Cradley Iron Works, near Brierley Hill.
1867. Swingler, Henry, Victoria Foundry, Litchurch, near Derby.
1859. Swingler, Thomas, Victoria Foundry, Litchurch, near Derby.

1861. Tangye, James, Cornwall Works, Clement Street, Birmingham.
1859. Tannett, Thomas, Victoria Foundry, Leeds.
1861. Taylor, George, Clarence Iron Works, Leeds.
1858. Taylor, James, Britannia Engine Works, Cleveland Street, Birkenhead.
1862. Taylor, John, Mining Engineer, 6 Queen Street Place, Upper Thames Street, London, E.C.
1867. Taylor, Joseph, Derwent Foundry, 99 Constitution Hill, Birmingham.
1862. Taylor, Richard, Mining Engineer, 6 Queen Street Place, Upper Thames Street, London, E.C.
1868. Taylor, Samuel, Clarence Iron Works, Leeds.
1864. Tennant, Charles, The Glen, Innerleithen, near Edinburgh. (*Life Member.*)
1867. Thomas, Joseph Lee, 7 Holland Terrace, Kensington, London, W.
1864. Thomas, Thomas, Llynvi Vale Iron Works, near Bridgend.
1857. Thompson, Robert, Haigh Foundry, near Wigan.
1862. Thompson, William, Spring Gardens Engine Works, Newcastle-on-Tyne.
1852. Thomson, George, Crookhay Iron Works, Westbromwich.
1868. Thomson, John, Engine Works, 36 Finnieston Street, Glasgow.
1865. Thorn, Alexander, Steam Saw Mills, Chelsea, London, S.W.
1868. Thornewill, Robert, Burton Iron Works, Burton-on-Trent.

1861. Thwaites, Robinson, Vulcan Iron Works, Thornton Road, Bradford, Yorkshire.
1865. Tickle, John, Providence Engine Works, Westbromwich.
1862. Tijou, William, 27 Great George Street, Westminster, S.W.
1862. Tolmé, Julian Horn, 1 Victoria Street, Westminster, S.W.
1857. Tomlinson, Joseph, Jun., Locomotive Superintendent, Taff Vale Railway, Cardiff.
1867. Tonks, Edmund, Brass Works, Moseley Street, Birmingham.
1865. Toomey, Edward, Royal Phœnix Iron Works, Dublin.
1856. Tosh, George, Locomotive Superintendent, Maryport and Carlisle Railway, Maryport.
1860. Townsend, Thomas C., 16 Talbot Chambers, Shrewsbury.
1863. Townsend, William, West Orchard, Coventry.
1865. Trow, John James, Timber Works, Bilston Road, Wednesbury.
1862. Troward, Charles, 8 Sussex Terrace, Camden Town, London, N.W.
1859. Turner, Edwin, Ashfield, Bradford, Yorkshire.
1866. Turner, Frederick, St. Peter's Iron Works, Ipswich.
1867. Turner, Henry, Thames Ship Building Works, Orchard Yard, Blackwall, London, E.
1867. Tweddell, Ralph Hart, 44 West Sunniside, Sunderland.
1856. Tyler, Captain Henry Wheetley, R.E., Railway Department, Board of Trade, Whitehall, London, S.W.

1862. Upward, Alfred, Engineer, Chartered Gas Works, 146 Goswell Street, London, E.C.
1865. Usher, George Moon, Beverley Iron Works, Beverley.

1868. Vallance, Frederick Bevoley, Alicel Engine Works, Bridge Street, Greenwich, S.E.
1862. Vavasseur, Josiah, 28 Gravel Lane, Southwark, London, S.E.
1856. Vernon, John, Regent Road, Sandon Dock, Liverpool.
1865. Vickers, Albert, Don Steel Works, Sheffield.
1861. Vickers, Thomas Edward, Don Steel Works, Sheffield.

1856. Waddington, John, 35 King William Street, London Bridge, London, E.C.
1856. Waddington, Thomas, Heaton Lodge, Wortley, near Leeds.
1865. Wainwright, William, Great Western Railway, Locomotive Department, Worcester.
1863. Wakefield, John, Locomotive Superintendent, Dublin Wicklow and Wexford Railway, Dublin.
1867. Walker, Benjamin, Goodman Street Works, Hunslet, Leeds.
1864. Walker, Bernard Peard, Junction Cut Nail Works, Wolverhampton.

1867. Walker, Charles Clement, Midland Iron Works, Donnington, near Newport, Shropshire.
1847. Walker, Thomas, Patent Shaft Works, Wednesbury.
1863. Walker, William Hugill, Wicker Iron Works, Sheffield.
1863. Wallace, William, Superintending Engineer, Montreal Ocean Steam Ship Works, Liverpool.
1865. Waller, George Arthur, Messrs. Guinness, James' Gate, Dublin.
1868. Wallis, Herbert, Midland Railway, Locomotive Department, Bradford, Yorkshire.
1865. Walpole, Thomas, Port of Dublin Ship Yard, Dublin.
1864. Warden, Walter Evers, Phœnix Bolt and Nut Works, Glover Street, Birmingham.
1856. Wardle, Charles Wetherell, Boyne Engine Works, Hunslet, Leeds.
1852. Warham, John R., Burton Iron Works, Burton-on-Trent.
1867. Watkin, William John Laverick, Mining Engineer, Pemberton Colliery, near Wigan.
1862. Watkins, Richard, Canal Iron Works, Poplar, London, E.
1866. Watson, Robert, Engineer, Black Boy Collieries, Bishop Auckland.
1862. Webb, Francis William, Bolton Iron and Steel Works, Bolton.
1862. Webb, Henry Arthur, Bretwell Hall Iron Works, near Stourbridge.
1860. Weild, William, Tipping Street, Ardwick, Manchester.
1862. Wells, Charles, Moxley Iron Works, near Bilston.
1862. Westmacott, Percy G. B., Elswick Engine Works, Newcastle-on-Tyne.
1867. Weston, Thomas Aldridge, care of William T. Watts, 78 Parade, Birmingham.
1867. Wheatley, Thomas, Locomotive Superintendent, North British Railway, Edinburgh.
1856. Wheeldon, Frederick R., Highfields Engine Works, Bilston.
1864. White, Isaiah, Messrs. Portilla and White, Engineers and Iron Ship Builders, Seville, Spain: (or care of Isaac White, Pontardulais, Llanelly.)
1868. Whitehead, Peter Ormerod, Ilex Cotton Mill, Rawtenstall, near Manchester.
1862. Whitehead, William, Don Steel Works, Sheffield.
1859. Whitham, James, Perseverance Iron Works, Kirkstall Road, Leeds.
1863. Whitley, Joseph, New British Iron Works, Corngreaves, near Birmingham.
1866. Whitwell, Thomas, Thornaby Iron Works, Stockton-on-Tees.
1847. Whitworth, Joseph, Chorlton Street, Manchester.
1859. Wickham, Lamplugh Wickham, Low Moor Iron Works, near Bradford, Yorkshire.
1863. Wicksteed, Thomas, 8 Torquay Terrace, Headingley, near Leeds. (*Life Member.*)
1868. Wigham, John Richardson, Stafford Works, Stafford Street, Dublin.

1868. Wigram, Reginald, Steam Plough and Locomotive Works, Leeds.
1867. Wilkes, Gilbert, Tube Works, Bordesley Mills, Birmingham.
1867. Wilkes, John, Tube Works, Bordesley Mills, Birmingham.
1868. Wilkieson, Lt.-Colonel Charles Vaughan, R.E., care of Messrs. Richardson and Co., 13 Pall Mall, London, S.W.
1865. Williams, Edward, Messrs. Bolckow and Vaughan's Iron Works, Middlesbrough.
1847. Williams, Richard, Patent Shaft Works, Wednesbury.
1859. Williams, Richard Price, 37 Great George Street, Westminster, S.W.
1856. Wilson, Edward, 9 Dean's Yard, Westminster, S.W.
1859. Wilson, George, Cyclops Steel and Iron Works, Sheffield.
1867. Wilson, Henry, Brass Works, Stockton-on-Tees.
1865. Wilson, James Edwards, Engineer, Indian Branch Railways, Cawnpore, India.
1863. Wilson, John Charles, East India House, 5 Lime Street, London, E.C.
1852. Wilson, Joseph W., 19 Craven Street, Strand, London, W.C.
1857. Wilson, Robert, Bridgewater Foundry, Patricroft, near Manchester.
1860. Wilson, William, 4 Victoria Street, Westminster, S.W.
1865. Winby, Clifford Etches, Atlas Iron Works, Cardiff.
1867. Winby, Frederick Charles, Atlas Iron Works, Cardiff.
1862. Winby, William Edward, Old Park Iron Works, Wednesbury.
1859. Winter, Thomas Bradbury, 28 Moorgate Street, London, E.C.
1863. Wise, Francis, Chandos Chambers, Buckingham Street, Adelphi, London, W.C.
1868. Wood, Lindsay, Mining Engineer, Hetton Colliery, Hetton, near Fence Houses.
1865. Woodall, Solomon, Windmill End Boiler Works, near Dudley.
1848. Woodhouse, Henry, London and North Western Railway, Stafford.
1851. Woodhouse, John Thomas, Mining Engineer, Midland Road, Derby.
1858. Woods, Hamilton, Liver Foundry, Ordsal Lane, Salford, Manchester.
1860. Worthington, Samuel Barton, Engineer, London and North Western Railway, Manchester.
1866. Wray, William, Ship Building Yard, Burton Stather, near Brigg.
1866. Wren, Henry, London Road Iron Works, Manchester.
1867. Wright, John Turner, Universe Rope Works, Garrison Street, Birmingham.
1859. Wright, Joseph, Metropolitan Carriage and Wagon Company, Saltley Works, Birmingham.
1860. Wright, Joseph, Neptune Forge, Tipton Green, Dudley.
1863. Wright, Owen, Broadwell Forge, Oldbury, near Birmingham.
1863. Wright, Peter, Railway Wheel Vice and Anchor Works, Dudley.
1865. Wyllie, Andrew, Vauxhall Foundry, Liverpool.
1853. Wymer, Francis W., Surveyor of Steam Vessels, Board of Trade, Greenock.

1861. Yule, William, 102 New Canal, St. Petersburg.

HONORARY LIFE MEMBERS.

1865. Downing, Samuel, LL.D., Museum Building, Trinity College, Dublin.
1847. Fairbairn, William, LL.D., The Polygon, Ardwick, Manchester.
1867. Morin, General Arthur, Director, Conservatoire Impérial des Arts et Métiers, Paris.
1867. Tresca, Henri, Engineer Sub-Director, Conservatoire Impérial des Arts et Métiers, Paris.

ASSOCIATES.

1865. Barker, Frederick, Leeds Iron Works, Leeds.
1868. Beale, Montague, 1 Great Winchester Street Buildings, London, E.C.
1867. Blinkhorn, William, London and Manchester Plate Glass Works, Sutton, St. Helen's.
1866. Chadwick, William, Monkbridge Iron Works, Leeds.
1848. Crosby, Samuel, Tenby House, Victoria Road, Aston, Birmingham.
1866. Crossley, John, British Plate Glass Works, Ravenhead, near St. Helen's.
1867. Dewhurst, John Bonny, Bellevue Cotton Mills, Skipton.
1863. Fisher, John, Priory Street, Dudley.
1863. Forster, George Emmerson, Collingwood Chambers, Newcastle-on-Tyne.
1865. Gössell, Otto, 22 Moorgate Street, London, E.C.
1865. Hall, John, 56 King Street, Manchester.
1864. Hornblower, Joseph Wells, 14 Waterloo Street, Birmingham.
1858. Lawton, Benjamin C., 44 Westgate Street, Newcastle-on-Tyne.
1859. Leather, John Towlerton, Leventhorpe Hall, near Leeds. (*Life Associate.*)
1865. Longsdon, Alfred, 11 New Broad Street, London, E.C.
1860. Manby, Cordy, Tower Street, Dudley.
1868. Matthews, Thomas Bright, Globe Steel Works, Sheffield.
1867. Neave, William Alexander, Poste Restante, Lausanne, Switzerland.
1863. Nichols, William, Midland Copper Works, Guild Street, Burton-on-Trent.
1865. Parry, David, Leeds Iron Works, Leeds.
1864. Parsons, Charles T., Ann Street, Birmingham.
1856. Pettifor, Joseph, Midland Railway, Derby.
1861. Ratcliff, Charles, Wyddrington, Edgbaston, Birmingham.
1863. Rigg, Arthur, The College, Chester.
1867. Roe, Thomas, Jun., Siddals Road, Derby.
1866. Scott, John Peers, 10 Tib Lane, Cross Street, Manchester.
1859. Sherriff, Alexander Clunes, M.P., Great Western Railway, Worcester.
1863. Storey, Thomas R., Bond Court House, Walbrook, London, E.C.

1864. Tennant, John, St. Rollox Chemical Works, Glasgow. (*Life Associate.*)
1864. Thornton, Falkland Samuel, Bradford Street, Birmingham.
1865. Warden, Thomas, Lionel Street, Birmingham.
1848. Warden, William Marston, Edgbaston Street, Birmingham.
1858. Waterhouse, Thomas, Claremont Place, Sheffield.
1867. Watts, William Thomas, 78 Parade, Birmingham.
1866. White, Richard Lewis, Great Western Railway, Swindon.
1865. Whitley, Joseph, Bowman Lane, Leeds.
1863. Woolley, John, Marehay Colliery, Ripley, near Derby.

GRADUATES.

1866. Butler, James, Atlas Works, Manchester.
1866. Butler, Thomas Snowden, Kirkstall Forge, Leeds.
1867. Cuss, Nevil John, Great Western Railway, Locomotive Department, Swindon.
1867. Downes, James Charles, Midland Railway, Locomotive Department, Derby.
1868. Dugard, William Henry, 77 Lower Loveday Street, Birmingham.
1867. Flavel, Sidney, Jun., Eagle Foundry, Leamington.
1850. Glydon, George, Spring Hill Tube and Metal Works, Eyre Street, Birmingham.
1867. Hill, Henry Walker, 241 Dewsbury Road, Leeds.
1867. Holland, George, care of John Holland, Contractor, Northwich.
1866. Humphrys, Robert Harry, Deptford Pier, London, S.E.
1867. Jones, George Edward, Horseley Iron Works, Tipton.
1868. Mappin, Frank, Sheaf Works, Sheffield.
1867. Mayhew, Horace, Mining Engineer, Wigan.
1867. Mitchell, John, Swaithe Colliery, Barnsley.
1868. Moor, William, Jun., Hetton Colliery, Hetton, near Fence Houses.
1867. Pearson, John Edward, Spring Colliery, Ince Hall, near Wigan.
1866. Ryland, Frederick, Messrs. Kenrick's Works, Spon Lane, Westbromwich.
1867. Warden, Howard William, Horseley Iron Works, Tipton.
1868. Wicksteed, Joseph Hartley, Well House Foundry, Leeds.
1867. Wright, John Roper, Landore Steel Works, Swansea.

Fig. 1. *Vertical Section of Accumulator.*

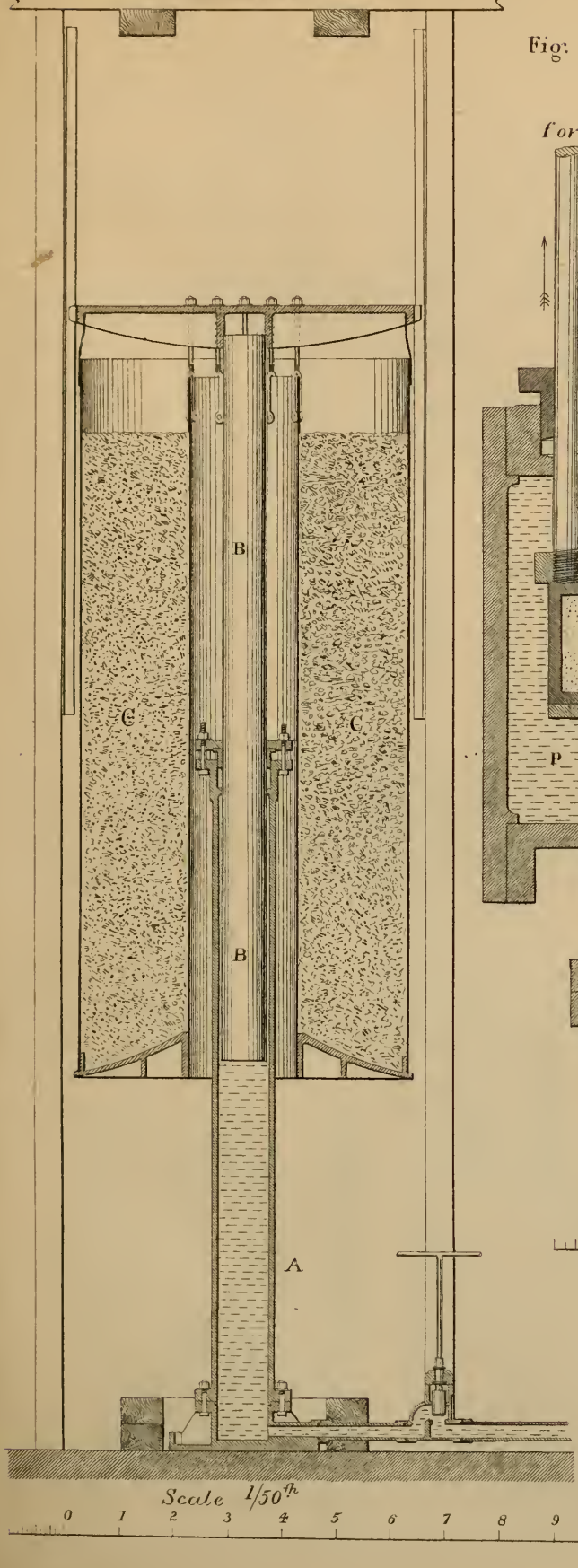
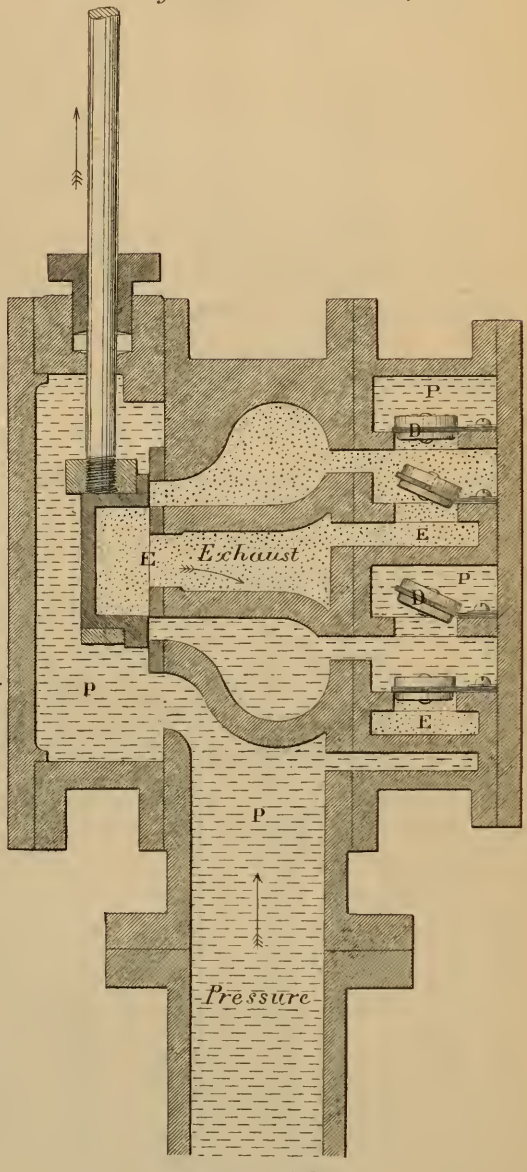


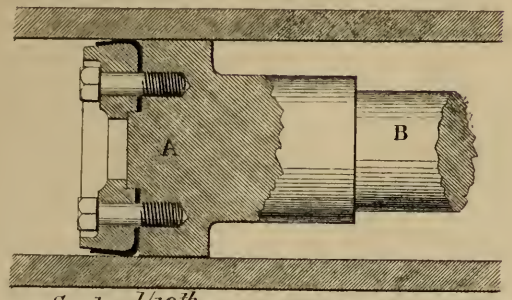
Fig. 2. *Section of Slide Valve and Relief Valves for Hydraulic Cranes, &c.*



(*Proceedings Inst. M. E. 1868*)

WATER PRESSURE MACHINERY.

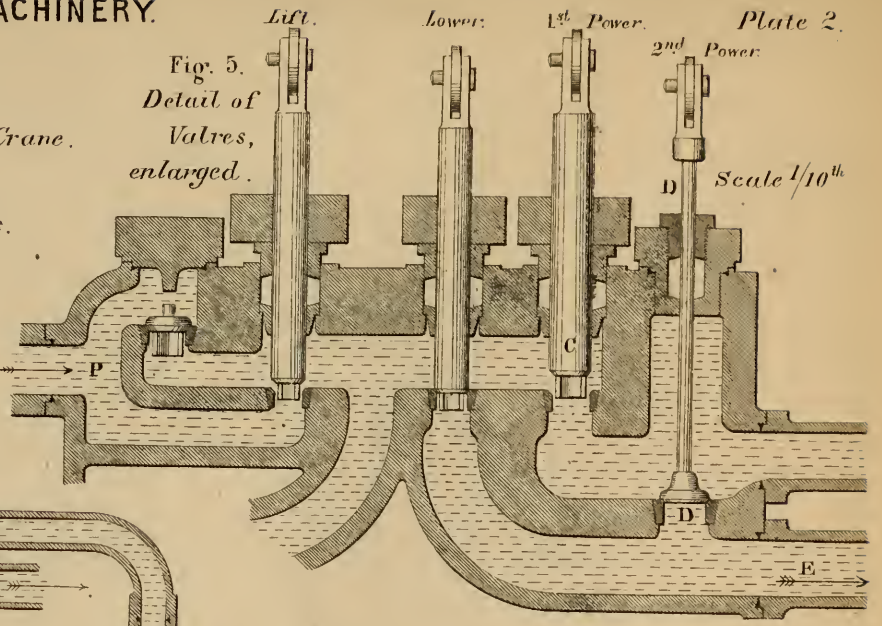
Fig. 4. *Section of Piston, enlarged.*



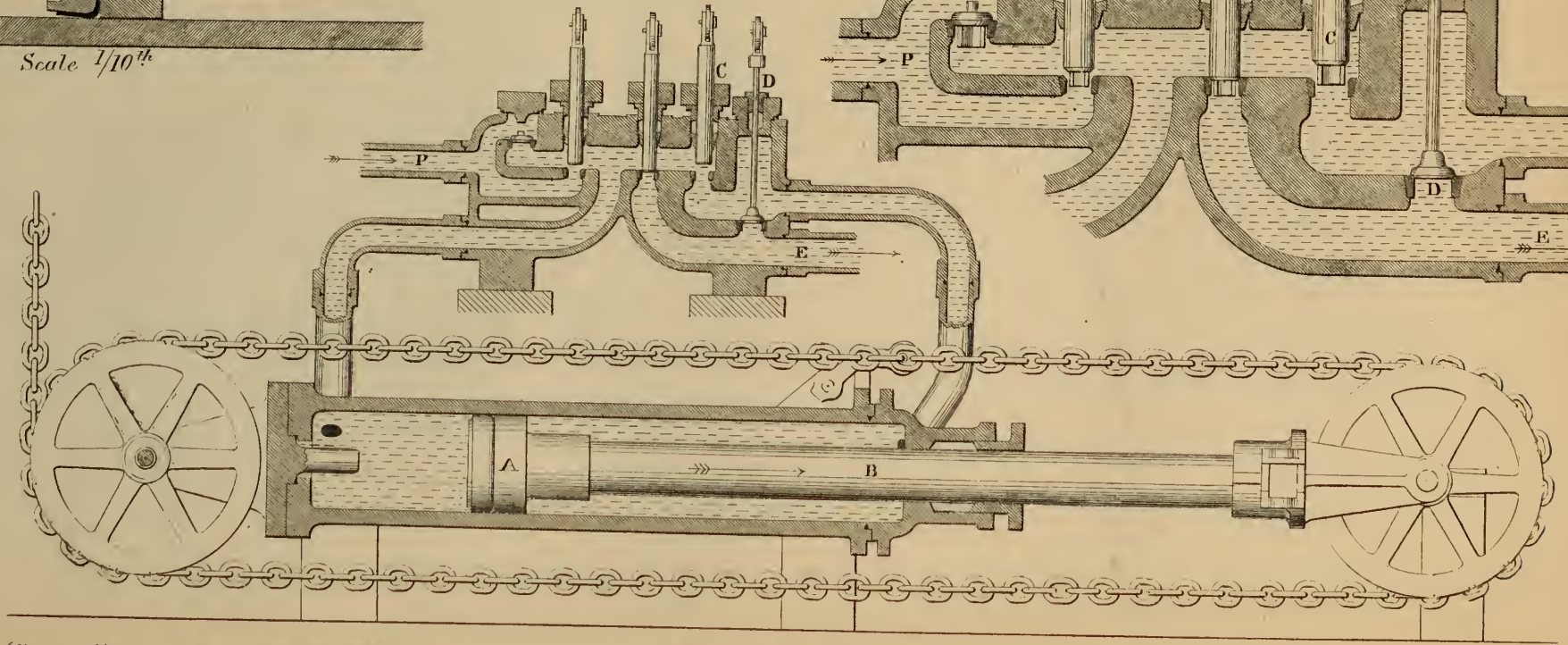
Scale 1/10th.

Fig. 3.
Double Power Hydraulic Crane.
Longitudinal Section of Cylinder and Valves.
Scale 1/20th.

Fig. 5.
Detail of Valves, enlarged.



Scale 1/10th.



(Proceedings Inst. M.E. 1868)

Scale 1/20th.

10 5 0 10 20 30 40 50 Inches.

Single-power Platform Crane for railway goods stations.

Fig. 6. *Elevation.*

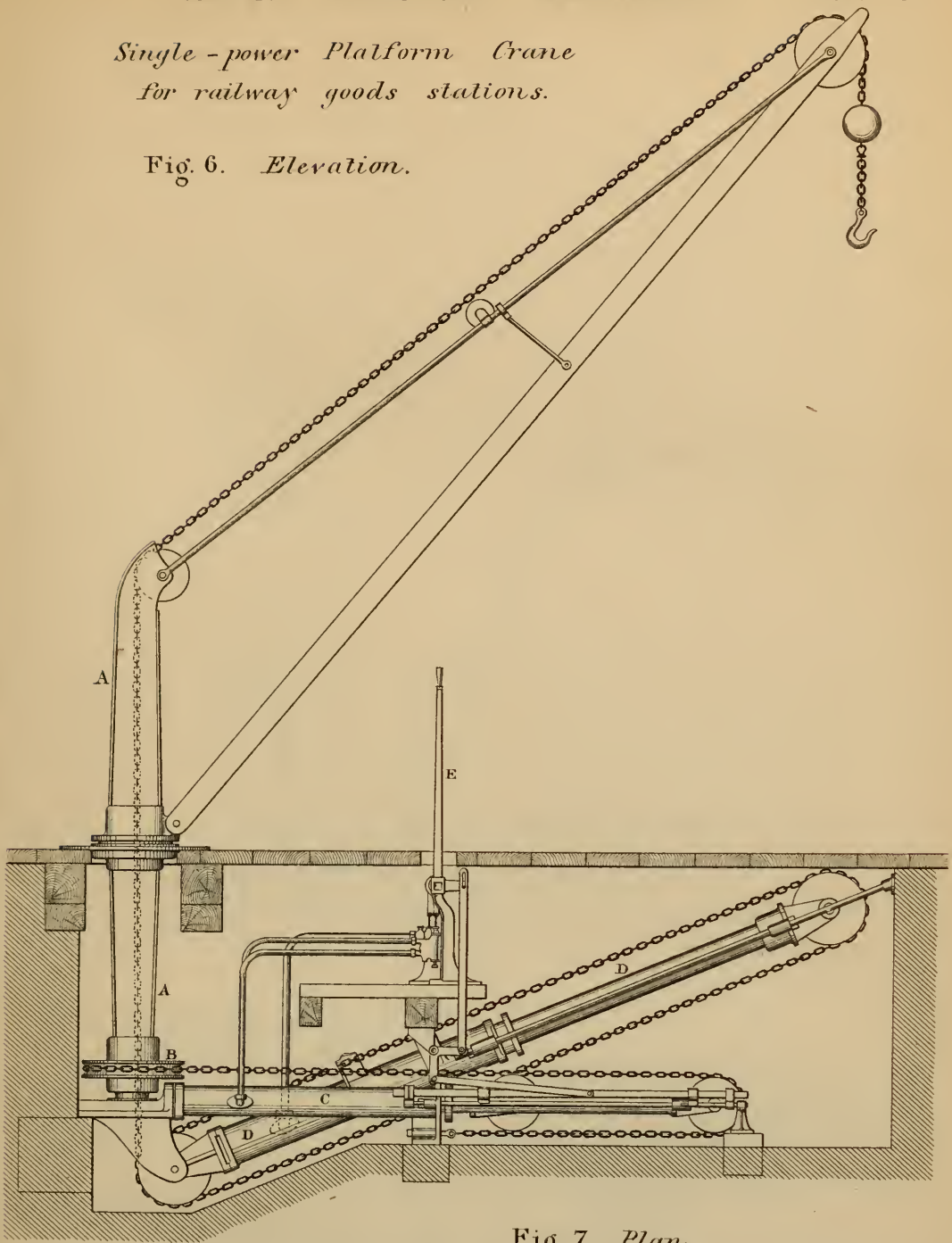
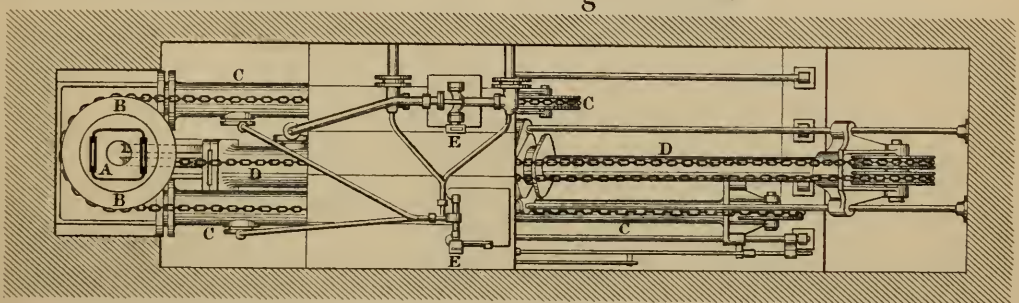


Fig. 7. *Plan.*

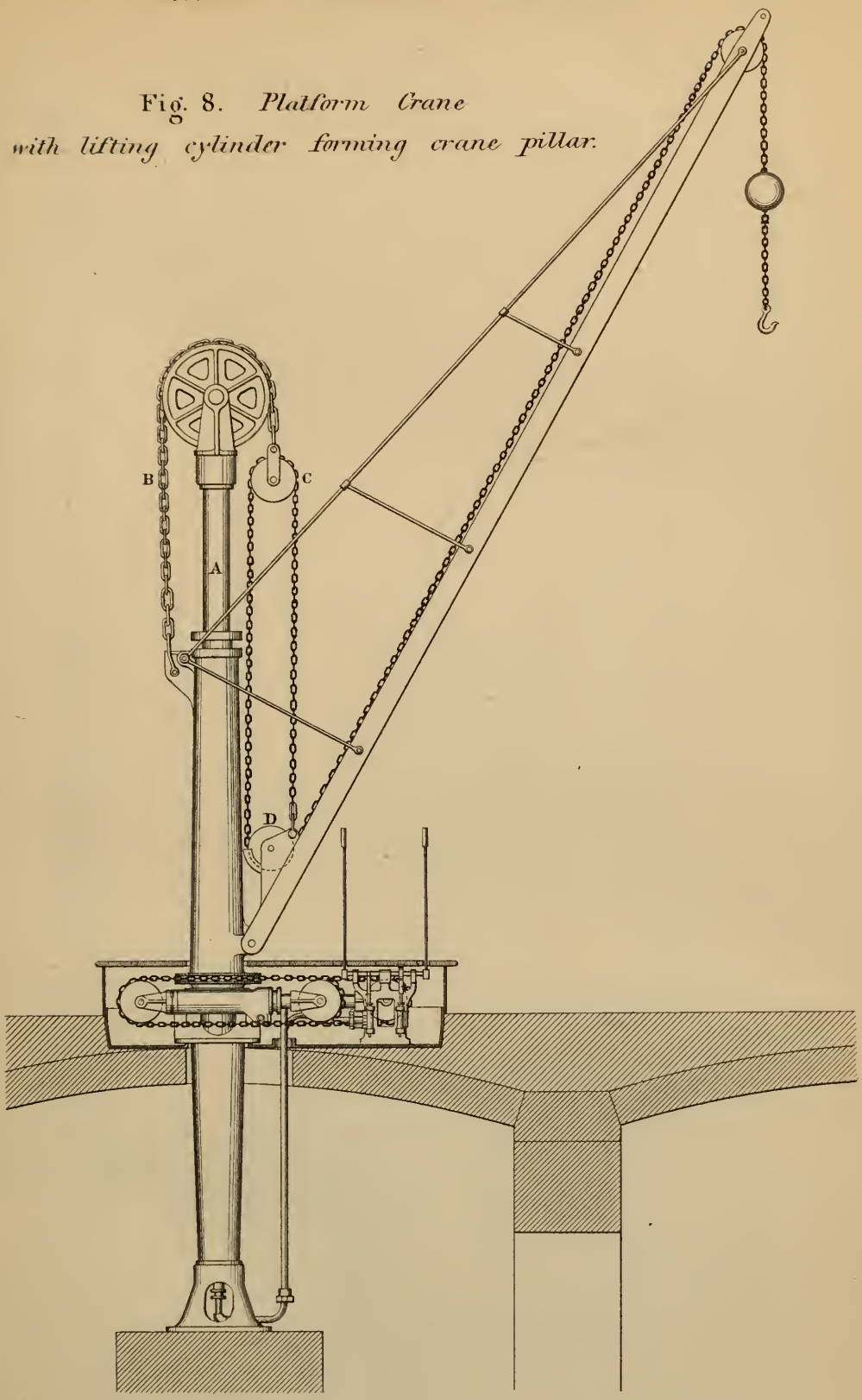


(Proceedings Inst. M.E. 1868.)

Scale 1/50th

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

Fig. 8. *Platform Crane with lifting cylinder forming crane pillar.*



(Proceedings Inst. M. E. 1868.)

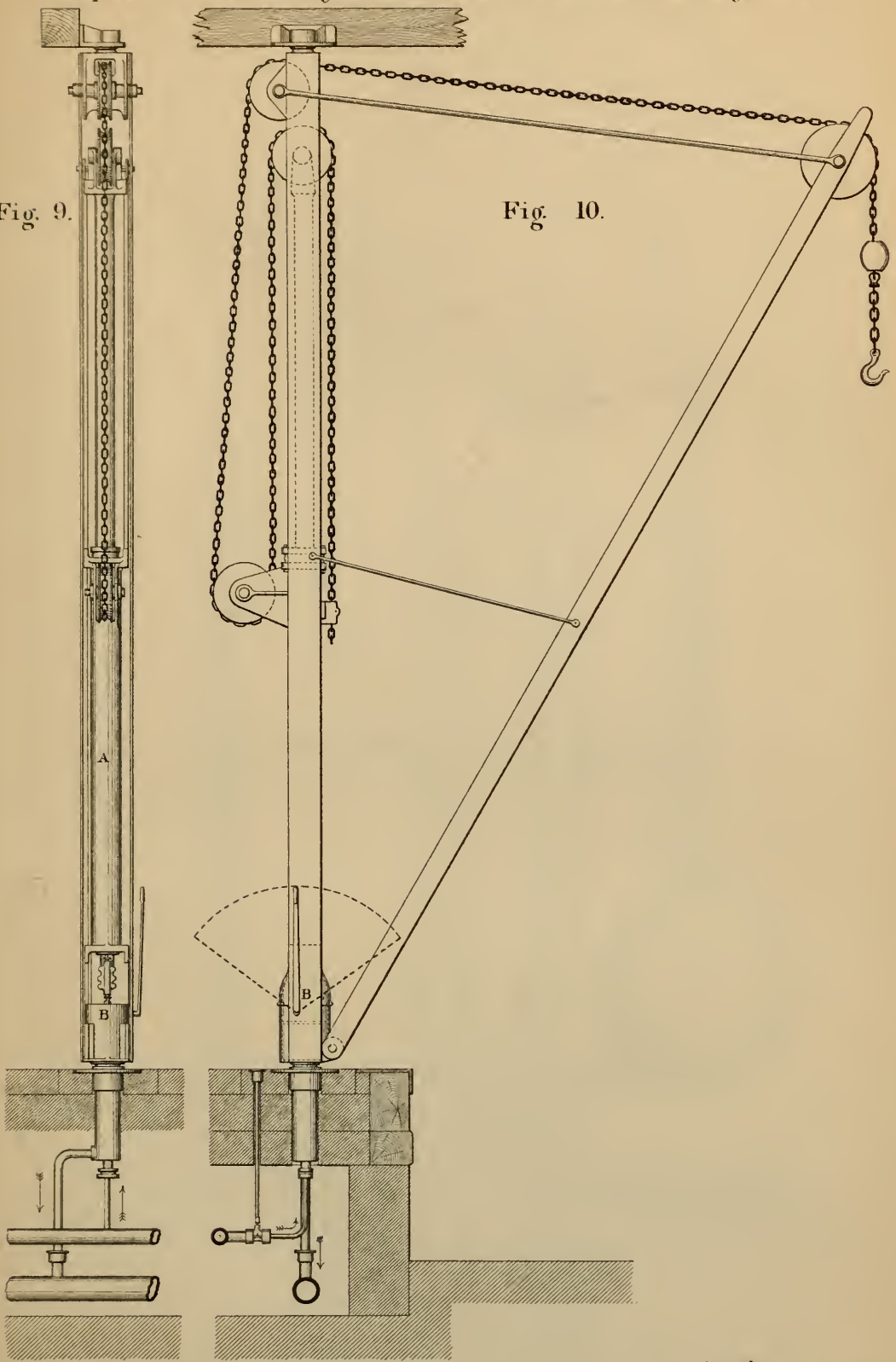
Scale 1/60th

0 5 10 15 Feet.

Simplest form of Hydraulic Crane, without turning power.

Fig. 9.

Fig. 10.

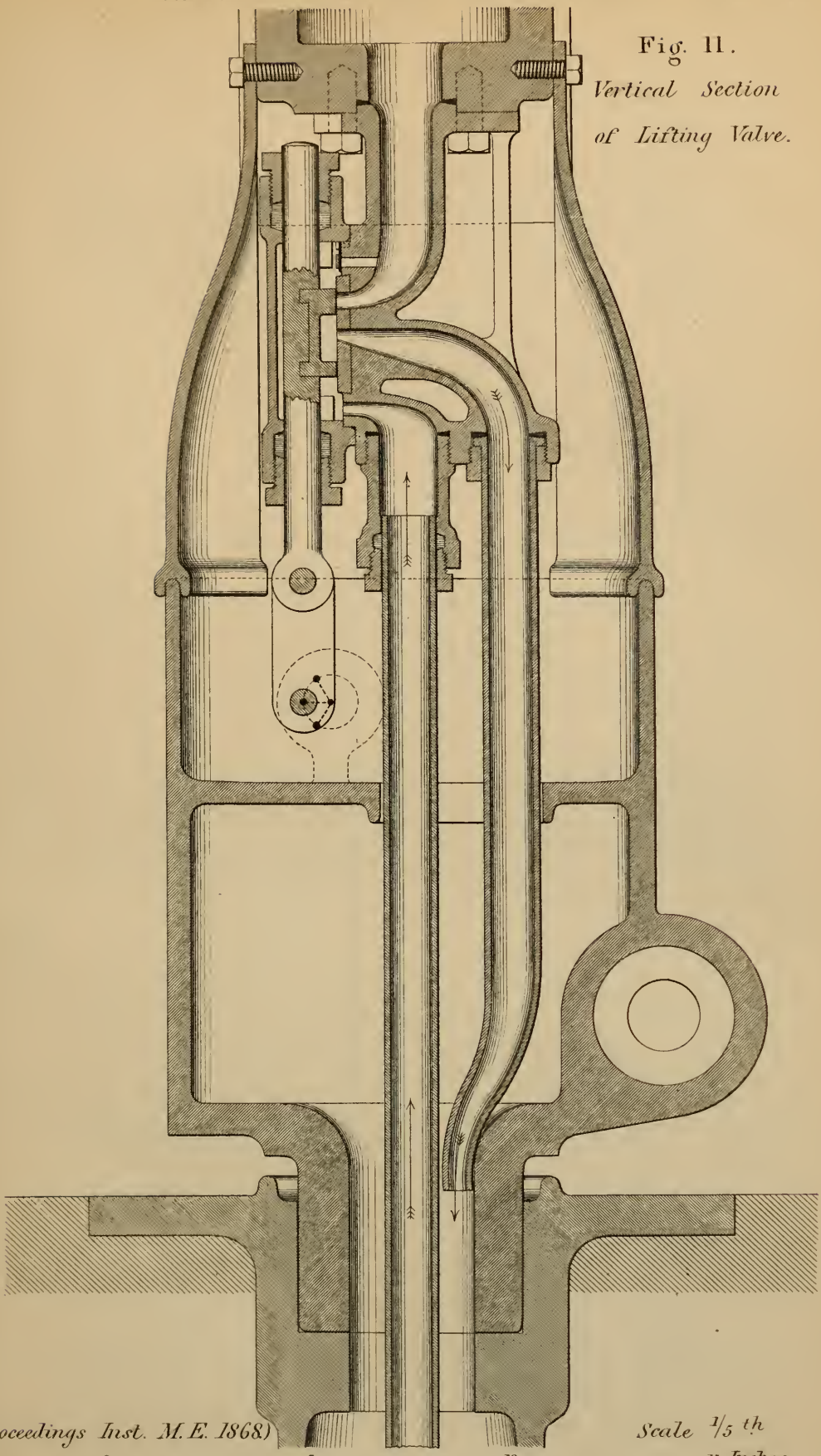


(Proceedings Inst. M.E. 1868.)

Scale 1/50th

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 *Feet.*

Fig. 11.
Vertical Section of Lifting Valve.



(Proceedings Inst. M.E. 1868)

Scale 1/5 *th*

0 5 10 15 *Inches.*

Fig: 12. *Side Elevation of Forge and Foundry Crane.*

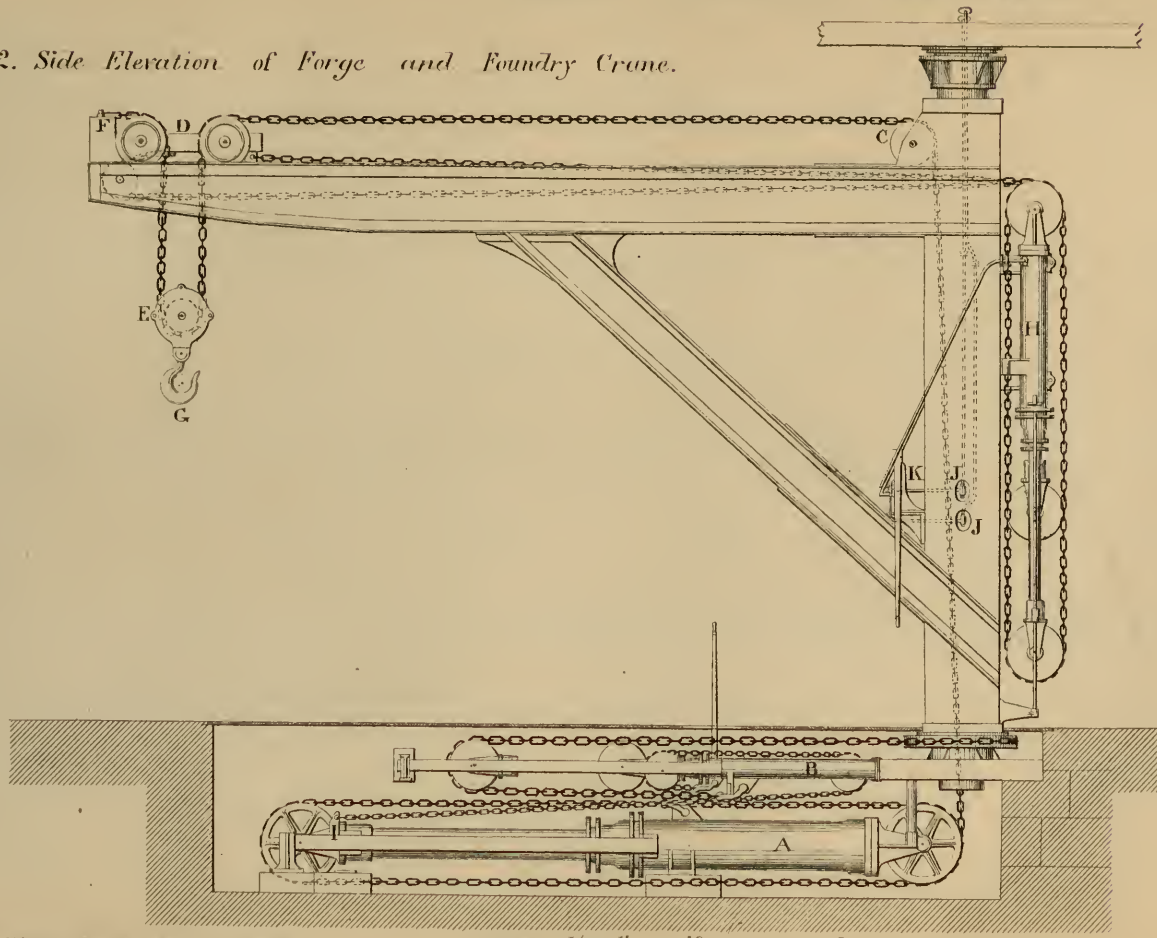
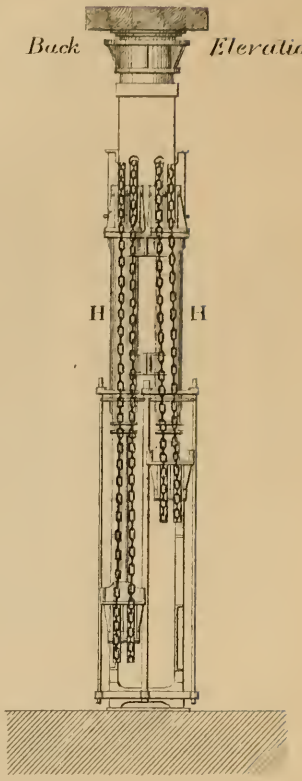


Fig: 13. *Back Elevation.*



(Proceedings Inst. M.E. 1868)

Scale 1/100th. 10 5 0 10 20 *Feet.*

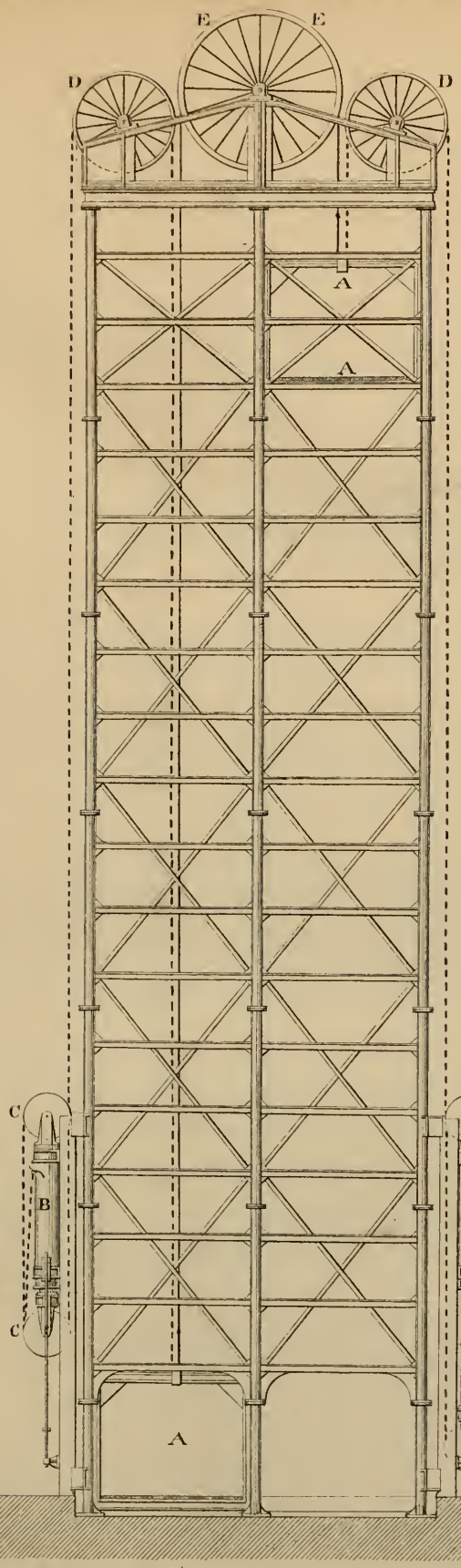


Fig: 14.
Blast-Furnace Hoist.

(Proceedings Inst. M.E. 1868)

Scale 1/160th

10 5 0 10 20 30 40Feet.

1 35

PROCEEDINGS.

30 January, 1868.

The Twenty-first Anniversary Meeting of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Thursday, 30th January, 1868; Sampson Lloyd, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.

1868.

The Council have great pleasure, on the occasion of the Twenty-first Anniversary of the Institution, in congratulating the Members upon the very satisfactory position and the continued progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December 1867 shows a balance in the Treasurer's hands of £4717 13*s*. 11*d*. after the payment of the accounts due to that date. The Finance Committee have examined and checked the receipts and payments of the Institution for the last year 1867, and report that the following Balance Sheet rendered by the Treasurer is correct. (*See Balance Sheet appended.*)

The Council report with great satisfaction the large increase in the number of Members that has taken place during the year; the total number of Members of all classes for the year being 791, of whom 4 are Honorary Life Members, 39 are Associates, and 17 are Graduates, being an effective increase of 63 during the year.

The following deceases of Members of the Institution have occurred during the past year 1867 :—

William Carpmael, Sen., . .	London.
Robert Hawthorn, ...	Newcastle-on-Tyne.
Edward Humphrys, ...	London.
William Jenkins, ...	Manchester.
Frederick Levick, ...	Blaina.
William Ryder, ...	Bolton.
Frank Shaw, ...	Burton-on-Trent.
Henry Wickham Wickham, . .	Bradford.

Of the above Members Mr. Robert Hawthorn was a Vice-President of the Institution for several years past, and Mr. Edward Humphrys a member of the Council, both of them having been Members of the Institution from the commencement.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year; and also of expressing their thanks to the Donors for the valuable and acceptable additions they have presented. The Council wish to urge on the attention of the Members the important advantage of obtaining a good collection of Engineering Books, Drawings, and Models or Specimens of interest in the Institution, for the purpose of reference by the Members personally or by correspondence; and they trust this desirable object will be promoted by the Members generally, so that by their united aid it may be efficiently accomplished. Members are requested to present copies of their Works to the Library of the Institution.

LIST OF DONATIONS TO THE LIBRARY.

On the State of Public Works in Spain; from Don José de Echeverria.
On the Construction of Iron Ships, by John Price; from the author.
Life and Times of the Marquis of Worcester, by Henry Dircks; from the author.
History of Perpetual Motion, do. do.
Memoir of Samuel Hartlib, do. do.
Optical Illusions, do. do.
Electro-Metallurgy, do. do.
On Applied Mechanics, by W. J. Macquorn Rankine; from the author.
On Apparent Negative Slip in Screw Steamers, do. do.
Report of the Smithsonian Institution for 1865; from the Institution.

Annual Report of the Secretary of War of the United States; from the Secretary.
Report of the Public Schools of Pennsylvania; from Mr. Edward Shippen.
Memoir of Parkin Jeffcock, by Rev. J. T. Jeffcock; from the author.
Stannah's Tables for Engineers; from the author.
Photographs of the Blackfriars Bridge Works; from Mr. Frederick W. Bryant.
Proceedings of the Institution of Civil Engineers; from the Institution.
Proceedings of the French Institution of Civil Engineers; from the Institution.
Bulletin of the French Society for the Encouragement of National Industry; from the Society.
Transactions of the Institution of Civil Engineers of Ireland; from the Institution.
Report of the British Association for the Advancement of Science; from the Association.
Proceedings of the South Wales Institute of Engineers; from the Institute.
Transactions of the Institution of Engineers in Scotland; from the Institution.
Transactions of the Society of Engineers; from the Society.
Proceedings of the Royal Institution of Great Britain; from the Institution.
Journal of the Hannover Architect and Engineers' Society; from the Society.
Journal of the Norwegian Polytechnic Society; from the Society.
Journal of the Royal United Service Institution; from the Institution.
Transactions of the Royal Scottish Society of Arts; from the Society.
Proceedings of the Philosophical Society of Glasgow; from the Society.
Report of the Royal Cornwall Polytechnic Society; from the Society.
Reports of the Manchester Association for the Prevention of Steam Boiler Explosions; from Mr. Lavington E. Fletcher.
Report of the Manchester Boiler Insurance Company; from Mr. Robert B. Longridge.
Reports of the Midland Steam Boiler Association; from Mr. Edward B. Marten.
Report of the British Association of Gas Managers; from the Association.
United States Patent Office Reports; from the Commissioner.
Journal of the Board of Arts and Manufactures for Upper Canada; from the Board.
Journal of the Society of Arts; from the Society.
The Engineer; from the Editor.
Engineering; from the Editor.
The Mechanics' Magazine; from the Editor.
The Civil Engineer and Architect's Journal; from the Editor.
The Artizan Journal; from the Editor.
The Practical Mechanic's Journal; from the Editor.
The Mining Journal; from the Editor.
The Railway Record; from the Editor.
The Steam Shipping Journal; from the Editor.

The Council have great satisfaction in referring to the number and character of the Papers that have been brought before the meetings during the past year, and the practical value and interest of the communications and the discussions that took place upon them, which form a valuable addition to the Proceedings of the Institution. The Council request the special attention of the Members to the importance of their aid and co-operation in carrying out the objects of the Institution and maintaining its advanced position, by contributing papers on Engineering subjects that have come under their observation, and communicating the particulars and results of executed works and practical experiments that may be serviceable and interesting to the Members; and they invite communications upon the subjects in the list appended and other subjects advantageous to the Institution.

The following Papers have been read at the Meetings during the last year:—

Description of the Paying-Out and Picking-Up Machinery employed in laying the Atlantic Telegraph Cable; by Mr. George Elliot, of London.

On the Composition and Durability of Locomotive Boiler Tubes in reference to Coal-Burning; by Mr. George A. Everitt, of Birmingham.

On the Ventilation of Public Buildings; by General Morin.

On Floating Docks, and other arrangements for affording access to Ships for external repairs; by Mr. Frederick J. Bramwell, of London.

On the "Flow of Solids," with the practical application in Forgings &c.; by M. Tresca.

On Mechanical Puddling; by Mr. William Menelaus, of Dowlais.

On the Machinery for Boring Artesian Wells; by M. Dru, of Paris.

On the Steam Dredgers employed in the excavation of the Isthmus of Suez Canal; by M. Borel, of Paris.

Description of a 30-Ton Horizontal Duplex Hammer; by Mr. John Ramsbottom, of Crewe.

Description of the Crossness Pumping Engines for the Metropolitan Main Drainage Works; by Mr. Gilbert Hamilton, of Messrs. James Watt & Co.

Description of an improved Steam Pile Driver with endless chain; by Mr. Peter B. Eassie, of Gloucester.

Description of the Steam Steering Engine in the "Great Eastern" steamship; by Mr. J. McFarlane Gray, of Liverpool.

The Council have particular pleasure in referring to the great success and the very gratifying results of the Annual Meeting of the Institution that was held in Paris last summer, during the time of the International Exhibition, which was supported by an unusually large attendance of the Members. The Council desire to express their special thanks to the authorities of the Conservatoire Impérial des Arts et Métiers, and to the Honorary Local Secretary, Mr. Henry Chapman, for the very excellent arrangements made for the Meeting and the very kind and cordial reception given to the Members on the occasion; and also their thanks to the proprietors of the works which were so liberally thrown open to the inspection of the Members, for the valuable opportunity afforded to the Members for seeing their works; and they refer specially to the opportunity of visiting the Observatory, upon the obliging invitation of the astronomer royal, M. Leverrier, and also the works of the Artesian Wells in progress of sinking in Paris. The Council look forward with confidence to the important advantages arising from the continuance of these Annual Meetings in different localities, from the facilities afforded by them for the personal communication of the Members in different districts, and from the opportunities of visiting the important Engineering Works that are so liberally thrown open to their inspection on those occasions.

The Council have the pleasure of reporting that an Honorary Life Membership in the Institution has been presented to General Morin, Director of the Conservatoire Impérial des Arts et Métiers, and also to M. Tresca, Engineer Sub-Director of the Conservatoire, as an expression of acknowledgment of the great obligation to them for the very important and valuable aid rendered by them on the occasion of the Paris Meeting of the Institution, as well as in recognition of their valuable contributions to Engineering Science.

The President, Vice-Presidents, and five of the Members of the Council in rotation, go out of office this day, according to the rules of the Institution; and the ballot will be taken at the present Meeting for the election of the Officers and Council for the ensuing year.

SUBJECTS FOR PAPERS.

STEAM ENGINE BOILERS, particulars of construction—form and extent of heating surface—relative value of radiant surface and flue surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—density and heat of steam—superheated steam, simple or mixed with common steam—pressure gauges—safety valves—water gauges—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low-pressure and high-pressure—steel boilers—cast-iron boilers—welded boilers—incrustation of boilers, and means of prevention—corrosion of boilers, and means of prevention—effects of surface condensers on the metal of boilers—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working—plans for heating feed water—mode of feeding—use of injector—circulation of water.

STEAM ENGINES—expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—combined engines—compound cylinder engines—comparative advantages of direct-acting and beam engines—engines for manufacturing purposes—horizontal and vertical—condensing and non-condensing—injection and surface condensers—air pumps—governors—valves—bearings, &c.—improved expansion gear—indicator diagrams from engines, with details of useful effect, consumption of fuel, &c.—contributions of indicator diagrams for reference in the Institution.

PUMPING ENGINES, particulars of various constructions—Cornish engines, beam engines with crank and flywheel, direct-acting engines with and without flywheel—size of steam cylinder and degree of expansion—number and size of pumps, and strokes per minute—speed of piston—pressure upon pump—effective horse power and duty—comparison of double-acting and single-acting pumping engines—construction of pumps—plunger pumps—bucket pumps—particular details of different valves—india-rubber valves, durability and results of working—diagrams of lift of valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.—sewage pumping engines—details of pit work of pumping engines in mines.

BLAST ENGINES, best kind of engine—size of steam cylinder, strokes per minute, and horse power—details of boilers—size of blowing cylinder, and strokes per minute—pressure of blast, and means of regulation—construction of valves—improvements in blast cylinders—rotary blowing machines—indicator diagrams from air main and steam cylinder.

MARINE ENGINES, power of engines in proportion to tonnage—different constructions of engines, double cylinder engines, trunk engines—three-cylinder engines—use of steam jackets—dynamical effect compared with indicator diagrams—comparative economy and durability of different boilers, tubular boilers, flat-flue boilers, &c.—brine pumps, and means of preventing deposit—salinometers—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in form and position, number of arms, material, means for unshipping, bearings, horse power applied, speed obtained, section of vessel—reaction propellers—governors and storm governors.

ROTARY ENGINES, particulars of construction and practical application—details of results of working.

LOCOMOTIVE ENGINES, particulars of construction, details of experiments, and results of working—consumption of fuel—relative value and evaporative duty of coke and coal—consumption of smoke—use of wood and construction of spark arresters—heating surface, length and diameter of tubes—material of tubes—experiments on size of tubes and blast pipe—construction of pistons, valve gear, expansion gear, &c.—indicator diagrams—expenses of working and repairs—means of supplying water to tenders—locomotives for steep gradients and sharp curves—distribution of weight on wheels.

AGRICULTURAL ENGINES, details of construction and results of working—duty obtained—application of machinery and steam power to agricultural purposes—barn machinery—field implements—traction engines, particulars of performance and cost of work done.

CALORIC ENGINES—engines worked by gas, or explosive compounds—electro-magnetic engines—particulars and results.

HYDRAULIC ENGINES, particulars of application and working—pressure of water—construction and arrangement of valves, relief valves—construction of joints—hydraulic rams.

WATER WHEELS, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, percentage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy—transmission of power to distant points.

WIND MILLS, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

CORN MILLS, particulars of improvements—power employed—application of steam power—results of working with an air blast and ring stones—crushing by rolls before grinding—advantages of regularity of motion.

Sugar Mills, particulars of construction and working—results of application of the hydraulic press in place of rolls—application of steam and water for extracting the last portion of saccharine matter—construction and working of evaporating pans.

Oil Mills, facts relating to construction and working, by stampers, by screw presses, and by hydraulic presses—particulars of crushing rollers and edge stones.

Cotton Mills, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning, carding, and winding machinery, &c.

Calico-Printing and Bleaching Machinery, particulars of improvements.

Wool Machinery, carding, combing, roving, spinning, &c.

Flax Machinery, manufacture of flax, china grass, and other fibrous materials, both in the natural length of staple and when cut.

Weaving Machinery, for manufacture of different materials—improvements in looms, &c.

Rope-Making Machinery—hemp and wire ropes, comparative strength, durability, and cost—steel wire ropes—transmission of power by ropes, percentage of loss, distance, wear of ropes, &c.

Saw Mills, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws—endless band saws.

Wood-Working Machines, morticing, dovetailing, planing, rounding, and surfacing—copying machinery.

Glass Machinery—manufacture of plate and sheet glass—construction of heating furnaces, annealing kilns, &c.—grinding and polishing machinery.

Lathes, Planing, Boring, Drilling, Slotting, and Shaping Machines, &c., particulars of improvements—description of new self-acting tools—engineers' tools—files and file-cutting machinery.

Rolling Mills, improvements in machinery for making iron and steel—mode of applying power—use of steam hammers—piling of iron—plates—fancy sections—arrangement and speed of rolls—length of bar rolled—manufacture of rolled girders—rolling of armour plates—reversing rolls.

Steam Hammers, improvements in construction and application—friction hammers—air hammers.

Riveting, Punching, and Shearing Machines, worked by steam or hydraulic pressure—direct-acting and lever machines—portable machines—comparative strength of drilled and punched plates—rivet-making machines.

Stamping and Coining Machinery, particulars of improvements, &c.

Locks, and lock-making machinery—iron safes.

Paper-Making and Paper-Cutting Machines, new materials and results.

Printing Machines, particulars of improvements, &c.—machines for printing from engraved surfaces—type composing and distributing machines.

Water Pumps, facts relating to the best construction, means of working, and application—velocity of piston—construction, lift, and area of valves.

Air Pumps, facts relating to the best construction, means of working, and application—velocity of piston—construction, lift, and area of valves.

Hydraulic Presses, facts relating to the best construction, means of working, and application—economical limit of pressure.

Rotary and Centrifugal Pumps, ditto ditto ditto.

Fire Engines, hand and steam, ditto ditto ditto.

Sluices and Sluice Cocks, worked by hand or hydraulic power, ditto.

Cranes—steam, hydraulic, and pneumatic cranes—travelling cranes.

Lifts for raising railway wagons—hoists for warehouses—safety apparatus.

Toothed Wheels, best construction and form of teeth—results of working—strength of iron and wood teeth—moulding by machinery.

Driving Belts and Straps, best make and material, leather, gutta-percha, vulcanised india-rubber, rope, wire, chain, &c.—comparative durability, and results of working—power communicated by certain sizes—frictional gearing, construction and driving power obtained—friction clutches—shafting and couplings.

Dynamometers, construction, application, and results of working.

Decimal Measurement—application of decimal system of measurement to mechanical engineering work—drawing and construction of machinery, manufactures, &c.—construction of measuring instruments, gauges, &c.

Strength of Materials, facts relating to experiments, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—rolled girders—best forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

Durability of Timber of various kinds—best plans for seasoning and preserving timber and cordage—results of various processes—comparative durability of timber in different situations—experiments on actual strength of timber.

Corrosion of Metals by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean—galvanic action, nature and preventives.

Alloys of Metals, facts relating to different alloys.

Friction of Various Bodies, facts relating to friction under ordinary circumstances—facts on increase of friction by reduction of surface in contact—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axleboxes—

wood bearings—water axleboxes—lubrication, best materials, means of application, and results of practical trials—best plans for oil tests—friction breaks.

Iron Roofs, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast-iron, wrought-iron, timber, &c.—best construction, form, and materials—details of large roofs, and cost.

Fire-proof Buildings, particulars of construction—most efficient plan—results of trials.

Chimney Stacks of large size—particulars, form, mode of building, cheapest construction, &c.—force of draught, and temperature of current.

Bricks, manufacture, durability, and strength—hollow bricks, fire bricks, and fire clay—perforated bricks, cost of manufacture, and advantages—dry-clay bricks—machines for brick-making—burning of bricks.

Gas Works, best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, cheapest mode of making—water gas, &c.—improvements in purifiers, condensers, and gasholders—wet and dry gas meters—self-regulating meters—pressure of gas, gas exhauster—gas pipes, strength and durability, and construction of joints—proportionate diameter and length of gas mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure—lighting railway trains with gas.

Water Works, facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—penetration of frost in different climates—relative advantages of stand pipes and air vessels—sluices and self-acting valves—machinery for working sluices—water meters, construction and working.

Well Sinking and Artesian Wells, facts relating to—boring tools, construction and mode of using.

Tunnelling Machines, particulars of construction, and results of working.

Cofferdams and Piling, facts relating to construction—cast-iron sheet piling.

Piers, fixed and floating, and pontoons, ditto ditto.

Pile Driving Apparatus, particulars of improvements—use of steam power—particulars of working—weight of ram and height of fall, total number of blows required—vacuum piles—compressed air system—screw piles—pile shoes.

Dredging Machines, particulars of improvements—application of dredging machines—power required and work done.

Diving Bells and Diving Dresses, facts relating to the best construction.

Lighthouses, cast-iron and wrought-iron, ditto ditto.

Ships, iron and wood—details of construction—lines, tonnage, cost per ton—water ballast—steel masts and yards, and wire-rope rigging—comparative strength and advantage of iron and wood ships—arrangements for docking and repairing ships—steering gear—application of steam power to steering.

Guns, cast-iron, wrought-iron, and steel—manufacture and proof—rifling—manufacture of shot and shells.

Small Arms, machinery for manufacture of rifles and cartridges, &c.

Mining Operations, facts relating to mining—modes of working and proportionate yield—coal-cutting machines—means of ventilating mines—use of ventilating machinery—safety lamps—lighting mines by gas—drainage of mines—sinking pits—mode of raising materials—safety guides—winding machinery—underground conveyance—stone-breaking machines—mode of breaking, pulverising, and sifting various descriptions of ores.

Blasting, facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder—arrangement of charges.

Blast Furnaces, shape and size—consumption of fuel—yield and quality of metal—pressure of blast—horse power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast—increased temperature of blast—construction and working of hot-blast ovens—pyrometers—construction of tuyeres—means and results of application of waste gas from close-topped and open-topped furnaces—preparation of materials for furnace and mode of charging.

Puddling Furnaces, best forms and construction—worked with coal, charcoal, &c.—application of machinery to puddling.

Heating Furnaces, best construction—consumption of fuel, and heat obtained.

Cupolas, construction and proportions—improvements in means of blowing—results of working, and economy of fuel.

Converting Furnaces, construction of furnaces—manufacture of steel—casehardening, &c.—converting materials employed.

Smiths' Forges, best construction—size and material—power of blast—hot blast, &c.—construction of tuyeres.

Smiths' Fans and Fans generally, best construction, form of blades, &c.—facts relating to power employed and percentage of effect produced—pressure and quantity of air discharged—size and construction of air mains—mechanical ventilation and warming of public buildings.

Coke and Charcoal, particulars of the best mode of making, and construction of ovens, &c.—open coking, mixtures of coal slack and other materials—evaporative power of different varieties—peat, manufacture of compressed peat.

Railways, construction of permanent way—section of rails, and mode of manufacture—mode of testing rails—experiments on rails, deflection,

deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

Switches and Crossings, particulars of improvements, and results of working.

Turntables, particulars of various constructions and improvements—engine turntables.

Signals for stations and trains, and self-acting signals.

Electric Telegraphs, improvements in construction and insulation—coating of wires—underground and submarine cables—mode of laying, and machinery employed.

Railway Carriages and Wagons, details of construction—proportion of dead weight.

Breaks for carriages and wagons, best construction—self-acting breaks—continuous breaks.

Buffers for carriages, &c., and station buffers—different constructions and materials.

Couplings for carriages and wagons—safety couplings.

Springs for carriages, &c.—buffing, bearing, and draw springs—range, and deflection per ton—particulars of different constructions and materials, and results of working.

Railway Wheels, wrought-iron, cast-iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought-iron and steel tyres, comparative economy and results of working—mode of fixing tyres—manufacture of weldless tyres, and solid wrought-iron wheels.

Railway Axles, best description, form, material, and mode of manufacture.

PREPARATION OF PAPERS.

The Papers to be written in the third person, on foolscap paper, on one side only of each page, leaving a clear margin of an inch width on the left side. In the subjects of the papers, extracts from printed publications and questions of patent right or priority of invention are not admissible.

The Diagrams to be on a large scale and strongly coloured, so as to be clearly visible to the meeting at the time of reading the paper. Enlarged details to be added for the illustration of any particular portions, drawn full size or magnified, with the different parts strongly coloured in distinctive colours. Several explanatory diagrams drawn roughly to a large scale in dark pencil lines and strongly coloured are preferable to a few small-scale finished drawings. The scale of each diagram to be marked upon it.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31*st December*, 1867.

Cr.	£.	*s.*	*d.*
By Balance 31st December, 1866	4152	2	7
„ Subscriptions from 22 Members in arrear	66	0	0
„ ditto from 2 Associates in arrear	6	0	0
„ ditto from 617 Members for 1867	1851	0	0
„ ditto from 33 Associates for 1867	99	0	0
„ ditto from 16 Graduates for 1867	32	0	0
„ ditto from 8 Members in advance for 1868	24	0	0
„ ditto from 1 Graduate in advance for 1868	2	0	0
„ ditto from 1 Life Member	30	0	0
„ Entrance Fees from 84 New Members	168	0	0
„ ditto from 7 New Associates	14	0	0
„ ditto from 12 New Graduates	12	0	0
„ ditto from 1 Graduate transferred to Member	1	0	0
„ Sale of Extra Reports	12	4	0
„ Interest from Bank	70	19	8
	£6540	6	3

Dr.				£.	*s.*	*d.*
To Printing and Engraving Reports of Proceedings	683	18	9			
Less Authors' copies of Papers, repaid	49	8	9	634	10	0
„ Stationery and Printing				67	6	1
„ Office Expenses and Petty Disbursements				93	5	3
„ Coals, Gas, and Water				18	4	3
„ Expenses of Meetings				289	0	3
„ Fittings and Repairs				16	18	5
„ Travelling Expenses				64	1	4
„ Parcels				10	6	0
„ Postages				82	5	0
„ Salaries				450	0	0
„ Insurance				2	8	3
„ Rent and Taxes				94	7	6
Balance 31st December, 1867				4717	13	11
				£6540	6	3

(Signed) EDWARD JONES, WALTER MAY, } Finance Committee.

30*th January*, 1868.

MEMOIRS

OF MEMBERS DECEASED IN 1867.

William Carpmael was born in London on 27th February 1804, and after receiving an ordinary mercantile education became assistant in the laboratory of a chemist named Kellerman at Luton in Bedfordshire, where he remained for two years and obtained a knowledge of the rudiments of chemistry. He afterwards became a pupil of the late Professor Millington, with whom he studied for some years, and under whose supervision he prepared, amongst other engineering works, the working drawings of the bridge over the Thames at Great Marlow, the erection of which he also superintended. Subsequently he designed and erected salt works in Cheshire for the late Mr. Furnival, and these works he managed for some time. Having however become connected with the late Mr. Poole, the attorney-general's clerk of the patents, with whom he subsequently entered into partnership in 1835 as a patent agent and consulting engineer, he ceased to occupy himself with the constructive branch of engineering. The general knowledge of law which he now required, he obtained by reading with a special pleader, the late Mr. Colman of the Temple; he also qualified himself for the bar, though never called, and was a member of Lincoln's Inn. In the consideration of engineering questions he specially excelled in his rapid and firm grasp of new mechanical ideas, and in the closeness and accuracy with which he was able to define them. He became first an Associate and afterwards a Member of the Institution of Civil Engineers, and for some time was on the Council. On the formation of the Metropolitan Board of Works he was elected a member of it, and remained so until his death, taking an active part in the promotion of the project for

the Main Drainage and for the Thames Embankment. He became a Member of this Institution in 1862; and died on 9th July 1867 at the age of 63.

Robert Hawthorn, of Elswick Lodge, Newcastle-on-Tyne, was born in 1797 at Dewley Burn near Walbottle Colliery, five miles west of Newcastle, his father being the engineer of the colliery. At an early age he was engaged under his father in the usual engineering work about the colliery, and occasionally in the construction of steam engines for various purposes, one special example being the pumping engine erected in 1816 at Brinkburn Colliery, which long after was considered a good specimen of his ability. In January 1817 he started works in Newcastle on his own account for the manufacture of steam engines, millwork, and cranes, &c.; and in 1820 was joined by his brother William, under the firm of R. and W. Hawthorn. In 1824 a 50 horse power double-acting condensing engine was made by them for the Plate Glass Works of Messrs. Cookson at Newcastle, which for many years was an object of much interest, and still continues to perform its duty satisfactorily and with precision. In the same year they introduced a self-acting steam travelling crane to discharge ballast from ships. In 1831 the firm commenced the manufacture of locomotive engines; and in 1835 they introduced fixed eccentrics for working the slide-valves of locomotives, and first applied them in the "Comet" engine supplied to the Newcastle and Carlisle Railway on the opening of the line in that year. Mr. Hawthorn became a Member of this Institution in 1848, and was one of the Vice-Presidents from 1864 to the time of his death, which occurred on 26th June 1867 at the age of 71.

Edward Humphrys was born at Bristol on 21st April 1810, and early devoted his attention to engineering. In 1832 he was in the service of the Dublin and London Steam Marine Company, and afterwards was manager for some time to Messrs. Rennie in London until 1848. In the following year he took the appointment of chief engineer at the Royal Dockyard, Woolwich, and after holding this

position for nearly three years went to Mr. Nasmyth at Patricroft; but shortly afterwards he returned to London, and in 1852 established engineering works at Deptford Pier, devoting his attention exclusively to marine engines. Here he was very successful, many improvements being introduced by him in the details of this class of engineering; and he was largely employed by the British and chief foreign governments. His latest efforts were devoted to designing engines of 1100 horse power, with 120 inch cylinders and $4\frac{1}{2}$ feet stroke, for the iron-clad turret ship "Monarch" building at Chatham. He died at Nice on 13th May 1867, aged 57 years. He was a Member of this Institution from the commencement in 1847, and for several years was on the Council.

William Jenkins was born in 1803 at Llandewi Brefi, a small village in Cardiganshire, South Wales, where his father was a millwright. After serving an apprenticeship to his father and to Messrs. Hughes and Wren in Manchester, he was engaged under the Liverpool Dock Corporation from 1826 to 1835, having charge of the engines and machinery employed in constructing the docks at the north end; and in 1830 he was sent to superintend the construction of the cranes and tramroads in a granite quarry in Scotland, from which the granite was procured for the Liverpool docks. In 1835 he was appointed to superintend the construction of the Manchester and Bolton Railway, the canal between the same places being also under his charge; and on the opening of the railway in 1838 he was appointed superintendent and manager of both the canal and the railway. Since the amalgamation of the Manchester and Bolton with the Lancashire and Yorkshire Railway in 1845 he held the office of locomotive superintendent of the amalgamated lines up to the time of his death, which occurred on 20th November 1867 at the age of 63, after a lingering illness. He introduced a plan for the consumption of smoke in coal-burning locomotives, which was extensively adopted by the Lancashire and Yorkshire Railway and other lines. He became a Member of this Institution in 1857.

Frederick Levick was born in London on 3rd July 1803, and commenced his career in 1825 at the Chillington Iron Works near Wolverhampton, and afterwards managed the Spring Vale Iron Works in the same district until 1844, when he went into Monmouthshire to take charge of the Blaina and Cwm Celyn Iron Works. In these works he shortly afterwards acquired a share, and in 1858 became proprietor of the whole of the works, in conjunction with his son-in-law, Mr. Robert Simpson, with whom he carried on the works till his death. He was one of the first to carry out successfully the utilisation of the waste gas from blast furnaces, which he commenced in 1849, and a description of the method employed for taking off the gas at Cwm Celyn was given to this Institution in Mr. Blackwell's paper on the subject in 1852; the make of the furnaces was also largely increased by Mr. Levick about the same time to 270 tons per week from each furnace. He was the first to roll the Barlow rail, of which for many years he made large quantities, rolling some as heavy as 100 lbs. per yard and 27 feet long. During the 23 years that he had the control of these works he got them into a very perfect condition, and brought up the make of iron to a very large amount; but in the last three years of his life he suffered very heavy reverses, which told seriously on his health; and he was in a weak state for some time previous to his death, which took place at Mr. Simpson's residence in Buckinghamshire on 5th November 1867 at the age of 64. He became a Member of this Institution in 1856.

William Ryder was born in 1808 at Turvin near Sowerby, Yorkshire, and afterwards removed to Bury, Lancashire, where his father was employed as manager in a cotton mill. When about seventeen years of age he went to Bolton, and about 1835 commenced business there as a spindle and fly maker. In 1840 he invented the forging machine so well known in connection with his name, for the simplification of smiths' work, which is now in general use in the principal engineering works both in this country and on the continent. To meet the increased business consequent upon this invention he established works in 1844 in Bark Street, Bolton, which were subsequently enlarged to a considerable size. He died on

21st January 1867 at the age of 58, after a short illness resulting from a severe cold. He became a Member of this Institution in 1863.

Frank Shaw was born at Stockport in 1840; and after serving his apprenticeship with Mr. E. T. Bellhouse, Eagle Foundry, Manchester, he remained for some time at the same works. In March 1864 he went to Burton-upon-Trent, as draughtsman to the engineering firm of Messrs. Thornewill and Warham, and in 1866 became manager to that firm. His death took place at Anerley near London on 9th September 1867 at the age of 27. He became a Member of this Institution in 1866.

Henry Wickham Wickham, M.P. for Bradford, Yorkshire, was born in 1800, being the son of Rev. Lamplugh Hird, prebendary of York. He was one of the leading partners in the Low Moor Iron Works near Bradford, and for many years took an active part in the management of the works, but ceased to do so in 1847. In 1852 he was returned to parliament as member for Bradford, and continued to represent that borough until the time of his death, which occurred at Leamington on 23rd September 1867 at the age of 67. He was chairman of the Lancashire and Yorkshire Railway for a long period; and was also a deputy-lieutenant for the West Riding of Yorkshire, and chairman of the West Riding quarter sessions. He became a Member of this Institution in 1859.

The CHAIRMAN moved that the Report of the Council be received and adopted, which was passed.

The CHAIRMAN announced that the Ballot Lists had been duly opened, and the following Officers and Members of Council were found to be elected for the ensuing year :—

PRESIDENT.

JOHN PENN, ... London.

VICE-PRESIDENTS.

JOHN ANDERSON, ... Woolwich.
FREDERICK J. BRAMWELL, . . London.
THOMAS HAWKSLEY, ... London.
SAMPSON LLOYD, ... Wednesbury.
JOHN RAMSBOTTOM, ... Crewe.
C. WILLIAM SIEMENS, . . . London.

COUNCIL.

CHARLES EDWARDS AMOS, . . . London.
WILLIAM CLAY, ... Liverpool.
EDWARD A. COWPER, ... London.
EDGAR GILKES, ... Middlesbrough.
THOMAS GREENWOOD, ... Leeds.
GEORGE HARRISON, ... Birkenhead.
WILLIAM MENELAUS, ... Dowlais.
W. MONTGOMERIE NEILSON, . . Glasgow.
CHARLES P. STEWART, ... Manchester.

PAST-PRESIDENTS.

Ex-officio permanent Members of Council.

SIR WILLIAM G. ARMSTRONG, . . Newcastle-on-Tyne.
WILLIAM FAIRBAIRN, ... Manchester.
JAMES KENNEDY, ... Liverpool.
ROBERT NAPIER, ... Glasgow.
JOSEPH WHITWORTH, ... Manchester.

COUNCIL.

Members of Council remaining in office.

Alexander Allan,	Worcester.
Charles Cochrane,	Dudley.
John Fernie,	Leeds.
Sir Charles Fox,	London.
Walter May,	Birmingham.
John Robinson,	Manchester.

TREASURER.

Henry Edmunds,	Birmingham.

SECRETARY.

William P. Marshall,	Birmingham.

The following New Members were also elected:—

MEMBERS.

Joseph Breeden,	Birmingham.
William Dean,	Wolverhampton.
Andrew Fairbairn,	Leeds.
Thomas Horsley, Jun.,	Alfreton.
Thomas Stuart Kennedy,	Leeds.
Lt.-Colonel Charles Vaughan Wilkieson, R.E.,	Madras.

The following paper was then read:—

ON THE TRANSMISSION OF POWER BY WATER PRESSURE, WITH THE APPLICATION TO RAILWAY GOODS STATIONS, FORGE AND FOUNDRY CRANES, AND BLAST-FURNACE HOISTS.

By Sir WILLIAM G. ARMSTRONG.

The employment of Water Pressure for the conveyance and distribution of power has been extended to many new purposes since the previous paper on the subject that was communicated by the writer to this Institution at the Newcastle Meeting in 1858 (see Proceedings Inst. M. E. 1858, page 126.) The most distinctive feature in this mode of transmitting power is the apparatus termed the "accumulator," shown in Fig. 1, Plate 1, which is so named because it accumulates the power exerted by the engine in charging it. It consists of a large cast-iron cylinder A, fitted with a plunger B, from which a loaded weight-case C C is suspended, to give pressure to the water pumped in by the engine. The accumulator is in fact a reservoir giving pressure by load instead of by elevation; and its purpose is to equalise the strain upon the engine in cases where the quantity of power to be supplied is subject to great and sudden variations. The load upon the plunger of the accumulator is generally such as to produce a pressure equal to that of a column of water 1500 feet high, and the capacity of the cylinder is sufficient to contain the largest quantity of water which can be drawn from it at once by the simultaneous action of all the machines in connection with it. The accumulator also serves as a regulator to the engine, for when the loaded plunger rises to a certain height it begins to close a throttle-valve in the steam pipe, so as gradually to lessen the speed of the engine until the descent of the loaded plunger again calls for an increased production of power. From the accumulator the water is conveyed by a pipe to the various places

where motive power is required; and in some cases where water is scarce it is returned by another pipe from the machines to the pumping engine to be again forced into the accumulator. The water thus acts merely as a carrier of power, and its function is consequently the same as that of shafting used for conveying the power of a steam engine to different parts of an establishment.

The question therefore to be considered is, in what respect or under what circumstances water pressure is superior to shafting for the transmission of power. It is not to be supposed that water pressure would be applicable as a substitute for shafting in mills and workshops where the machines to be driven are compactly grouped at short distances from the engine, and where they are generally continuous in their action. The superiority of water pressure is only realised in those instances where the machines to be put in motion are scattered over a wide area and are intermittent in their action, and also where the quantity of power to be transmitted is subject to great and abrupt variations. Upon an extended wharf, for example, every crane may happen to be in action at one moment, while at another time not one may be moving; and if shafting were used in such a case for conveying power to the cranes, the engine would sometimes be overtaxed and sometimes acting without any useful effect. But with water pressure as the medium of transmission, the variation of work is met by the accumulator; and the engine acts always under a uniform load, storing up its surplus power at times when the whole is not transmitted. Moreover the ramifications readily carried out in laying water pipes are not practicable with shafting, nor can shafting be extended beyond very limited distances.

Water pressure also possesses the advantage of communicating to machinery a much more controllable and adjustable motion than shafting. The water can be gradually turned on or shut off, and can be admitted as quickly or as slowly as may be desired; while with a shaft the motion acquired is sudden and cannot be communicated gradually. Another advantage of the hydraulic system is that the pipe conveying the water is itself at rest, and does not suffer any appreciable wear nor require any attention;

whereas a shaft being in motion is attended with friction and consequent wear, and involves constant lubrication.

The absence of elasticity in water gives great steadiness and precision to the movements of machines actuated by water pressure; but on the other hand, water being incapable of expanding like steam in a cylinder, the quantity expended is not proportionate to the load. Thus a machine propelled by hydraulic pressure measures off the same quantity of water, whatever may be the resistance overcome; and therefore when the machine is inadequately loaded the expenditure is more than equivalent to the effect produced. This loss of power may in a great measure be obviated by making the machines with variable powers; but the simplicity of single-power machines renders them preferable in many cases, notwithstanding their greater expenditure of power. In fact for the purposes to which water pressure is most usually applied, safety, simplicity, and general convenience are more to be considered than economy of power, because owing to the intermittent character of the work the required quantity of power is not large in the aggregate. It has also to be recollected that, although power is sacrificed by that very property in water which gives so much steadiness and safety to its action, yet the favourable condition under which a steam engine works when pumping against a constant head, as in charging an accumulator, cheapens the production of the power, and compensates for its more lavish application.

In connection with the non-elastic character of water, it will be observed that its incompressibility in the cylinder of the machines would, if not provided against, cause very injurious shocks and strains to the machinery, by suddenly arresting the momentum of the moving parts on the closing of the outlet passages. To obviate this liability, nearly all varieties of water-pressure machines adapted for rapid action require the introduction of what are termed "relief" valves. These have already been fully described in the writer's previous paper on water-pressure machinery; and it is therefore only necessary on this occasion to describe them as consisting of small clacks D D, as shown in Fig. 2, Plate 1, opening against the pressure

P in the supply pipes, and yielding to any back pressure on the pistons that exceeds the accumulator pressure. In the drawing P P represents the pressure, and E E the exhaust passages.

With a pressure equal to a column of water 1500 feet high, the loss of head by friction in the pipes forms a very inconsiderable deduction from the entire column; and the pressure may therefore be conveyed without any serious sacrifice to great distances from the engine. In some instances the length of the pressure pipes has been extended to more than two miles without any apparent decrease of effect; but in all cases where the pipe is very long it is desirable to apply an accumulator at each extremity, in order to charge the pipe from both ends. The most advantageous pressure of water for practical use seems to be that mentioned above, namely 1500 feet or about 700 lbs. per square inch. By increasing the pressure the size of the pipes and of all parts of the apparatus is lessened; but on exceeding the above limit a difficulty begins to be felt in preventing leakage and keeping the valves and packings in order; and this objection more than counterbalances the advantage of reducing the size of the apparatus.

Compressed air has often been proposed, and in some instances tried, as a medium for the transmission of power. Being elastic it has an advantage over water in accommodating its volume and consequently its expenditure to the load on the piston; but on the other hand it does not give back all the power put into it by the engine, because practically it cannot be used expansively to the full extent of its previous compression. In order to return all its acquired power, the air must undergo no throttling, and must be discharged from the cylinder in which it acts at the density of the atmosphere; and as these conditions are impracticable, the loss from elasticity in air is probably as great as that from the absence of elasticity in water. But the use of compressed air is subject to a far more serious source of waste by leakage, which in the case of air is very difficult to detect; and in an extended system of pipes and machines, requiring a multitude of joints, valves, and fitting surfaces, the leakage of the air must form an insurmountable difficulty. Moreover the elasticity of air deprives the machines to which it is applied of that perfect steadiness and precision which is

afforded by the incompressibility of water. Nor is any advantage to be gained by adopting the converse process of exhausting the air instead of compressing it, since the difficulties which apply to the one case are equally incident to the other.

The purposes to which water pressure has been applied as a means of transmitting power are exceedingly numerous; in fact in almost every case where manual labour is used as a mere motive power it may be superseded by engine power transmitted by means of water pressure. The widest application of this system is in docks, where the water-pressure machinery is now most extensively used in England for the purpose of opening and closing the gates, swing bridges, and sluices, and also for hauling ships through the locks and discharging and warehousing cargoes. It is also very generally employed in the various operations connected with the shipment and discharge of coal; and the mechanical arrangements applied to meet the different conditions under which these operations have to be performed are very various, and in some cases necessarily very elaborate. Perhaps the case of greatest novelty in this branch of the application of water pressure is that of a machine erected for the purpose of shipping coals at Goole Docks, on the river Humber, where barges containing 32 tons of coal are floated into a cradle, and then lifted bodily to a considerable height and turned over into a shoot, which delivers the coal into a ship alongside.

Water pressure as a medium for transmitting power has not yet been very extensively employed on the continent. In France it is in use at Marseilles, at Rouen, and at the Goods Station of the Paris and Lyons Railway in Paris, for the purpose of loading and unloading the wagons and also for hauling them in the station yard. The machinery at this station affords a good example of the application of the principle to railway goods traffic, and may therefore be selected for description.

The machines comprise fifteen single-power hydraulic platform cranes to lift $1\frac{1}{2}$ tons; and three double-power similar cranes, to lift $1\frac{1}{2}$ tons with the lower power, and 3 tons with the higher power;

also two hydraulic engines for driving capstan heads for hauling trucks.

The Single-power Cranes are represented in Figs. 6 and 7, Plate 3. They are adapted to turn as well as to lift and lower by the water pressure. The jib is a fixture to the crane pillar A, which is made to revolve by means of a chain passing round the cupped wheel B and worked by a pair of hydraulic presses C C. The diameter of the ram of each turning press C is 4 inches, and the length of stroke is 3 ft. 8 ins., which is doubled by passing the chain over a pulley at the end of the ram and fixing the extremity to the cylinder. The ram of the lifting press D is $5\frac{3}{4}$ inches diameter, and has a stroke of 4 ft. 8 ins., and the motion is multiplied four times by means of pulleys. The chain is conveyed upwards through the centre of the pillar A and thence over the end of the jib. The lifting cylinder D is placed at an angle, to facilitate the overhauling of the chain. The valves for lifting and lowering and for turning are slide valves, the lifting and lowering valve having two ports, and the turning valve three ports. Each valve is worked by a lever E passing through the platform, the two levers being placed at a proper distance apart so as to be worked by a man standing between them with a hand on each lever. To provide against the crane jib slewing round beyond the range of the turning presses, the turning valve is made to close by a self-acting arrangement at each extremity of the range.

The Double-power Crane is of the same general construction as the single-power; but instead of a simple hydraulic press with ram for lifting, a bored cylinder with a combined ram and piston is applied, as shown in Figs. 3 and 4, Plate 2. For the lower power the pressure is admitted upon both sides of the piston A, and therefore virtually acts only upon the ram B, which is half the area of the piston. For the higher power the front side of the piston is open to the exhaust E, leaving the pressure P to act on the back only, and the effect is then proportionate to the area of the piston, which is twice that of the ram. This alternative action is determined by the intervention of an extra valve C, Figs. 3 and 5; when this valve is opened, as shown in Fig. 5, the pressure P has access to both sides of

the piston, and the lower power is then obtained; while for the higher power the valve C is closed, and the exhaust valve D is opened, whereby the front side of the piston is kept constantly open to the exhaust E. In cases where three powers are required, three simple hydraulic presses are commonly used, which act either singly or in combination; but the same effect may be obtained with a bored cylinder and piston combined with two concentric rams, the external ram being secured by a pall when its action is not required, and the internal ram acting through a water-tight gland in the outer ram. In this case the lowest power is obtained by admitting the water only on the front side of the piston, whence it enters into the interior of the larger ram through a hole near the piston, and forces out the inner or smaller ram. The second power is obtained by admitting the water to both sides of the piston; and the highest power is brought into action by opening the front side of the piston to the exhaust, while the pressure operates on the back of the piston.

The Capstan Engines used at this railway station have each two oscillating cylinders with combined rams and pistons, working cranks at right angles; on the front side of the piston, which is half the entire area, the pressure is constant, and the back communicates alternately with the pressure and the exhaust. The engine therefore acts by a difference of pressure in one direction and by a positive pressure in the other, the effective pressure being equal in both cases; and the action is governed by a two-port slide-valve worked direct from the trunnion. In these engines, as well as in the cranes, "relief" valves are applied to prevent concussion from the water shut in.

Since the platform cranes of the Paris and Lyons Railway were constructed, a new arrangement of platform crane has been introduced, in which the lifting cylinder is arranged so as to form the crane pillar. An example of this kind of crane is shown in Fig. 8, Plate 4, where A is the lifting ram acting upon a chain B, which gives a twofold motion to a double-pulley running-block C. A corresponding double-pulley block D is fixed to the base of the jib, and over these pulleys the lifting chain passes four times, so that the range of the ram is multiplied altogether eight times at the outer end of the chain.

Another modification of the same kind of arrangement is exhibited in Figs. 9 and 10, Plate 5, where the crane pillar is carried in top and bottom bearings, and the lifting press A is placed between the two cheeks of the pillar. In this case there is no turning power, and the lifting valve B as well as the press is attached to the crane pillar, as shown to a larger scale in the section, Fig. 11, Plate 6. This is the simplest and cheapest form of hydraulic crane which is made. In all cases of cranes containing the lifting press in the pillar, the water is admitted through the pivot at the bottom, which is made water-tight by means of a cupped leather. For cranes of very high power, where only slow motions are required, it is now usual to employ the ordinary gearing of a steam crane, and to apply the water pressure by means of a small hydraulic engine fixed in the framework of the crane.

Hydraulic cranes have of late years been introduced with great advantage at the Elswick Works, both in the Forge and in the Foundry. In the forge they are applied to the service of a 12 ton hammer, and by this means forgings ranging in weight up to 20 tons are manipulated under the hammer with perfect precision and great saving of time and labour. In the foundry they are so applied as to command every part of the floor, and thus wholly to supersede manual labour for every purpose of lifting and carrying. The form of crane used in each of these departments is the same, and is represented in Figs. 12 and 13, Plate 7. The jib and pillar of the crane are of wrought iron, and revolve in top and bottom bearings. The crane has three motions, namely lifting, turning, and traversing, all of which are effected by hydraulic power. The lifting cylinder A is made of double power by the ram and piston arrangement before described, the highest power being equal to 20 tons; the ram is 11 inches diameter and the piston $15\frac{1}{2}$ inches diameter, the length of stroke being 6 ft. 8 ins. The turning cylinders B are applied in the usual manner at the foot of the crane pillar, the rams being each $4\frac{1}{4}$ inches diameter with 5 feet stroke; and both the lifting and the turning cylinders with their valves are fixed in a chamber beneath the level of the floor. A three-port slide-valve is used for the two

turning cylinders, and mitre valves for the lifting cylinder. The chain from the lifting cylinder is carried upwards through the crane pillar, bending over a sheave C at the top of the pillar, and passes successively over the pulleys of the travelling carriage D and the running block E, and is finally made fast at the extremity F of the jib. For the purpose of overhauling the ram of the lifting press, a small press is placed between the two turning presses B; and the overhauling action is effected by a chain and sheaves multiplying four times, the outer end of the chain being attached to the sliding head of the lifting ram at I. The pressure in the overhauling press is constant, and its action is therefore equivalent to that of a counterweight; the ram is $4\frac{1}{2}$ inches diameter with 3 ft. 5 ins. stroke. For effecting the traversing motion of the load suspended at the hook G, the travelling carriage D is hauled inwards and outwards by two presses H fixed to the back of the crane pillar, and connected by chains with the travelling carriage; the ram of each press is $5\frac{1}{2}$ inches diameter with 4 ft. 7 ins. stroke. The alternating action of these presses, which is precisely the same as that of the presses B used for the turning motion, is regulated by a three-port slide-valve K attached to the front of the pillar, with a lever at each side for working it. The water is supplied to and discharged from these presses by two pipes which pass through the top bearing of the pillar, and the connection between the valve and these pipes is effected in each case by a trunnion joint at J J.

Another novel purpose to which hydraulic pressure has recently been applied is the raising of the materials required for feeding Blast Furnaces. The great increase in the height, size, and productive power of modern blast furnaces has necessitated a great increase of speed and power in the lift; and the employment of water-pressure machines has fully satisfied these requirements. The apparatus employed for this purpose is represented in Fig. 14, Plate 8. The framework of the hoist is constructed of cast-iron columns supported by wrought-iron bracing. Two guided cages A A are used for receiving the barrows containing the materials to be raised to the furnace mouth; and two separate lifting-presses B B, one for each cage, are fixed in an inverted position against

opposite sides of the framing, the ram of each press being $11\frac{1}{2}$ inches diameter with a stroke of 8 feet. The lifting chain makes five turns over the pulleys C C of each press, so as to multiply the stroke tenfold, and is carried up over a sheave D at the top of the framing, and thence descends to the cage to which it is attached. The two cages are connected with each other by a wire rope which passes over a sheave E at the top of the framework, so that they balance each other, the one being lowered while the other is raised. The cages lift two barrows at a time, weighing with their contents $1\frac{1}{2}$ tons, and they are hoisted to the top at the rate of 4 feet per second; a much higher speed could be attained by increasing the size of the valves and pipes to the required extent. A three-port slide-valve is used for working the two presses, and admits the water to the one press while it discharges it from the other. The valve is worked at the bottom, but a rope is provided to enable it to be worked from the top as well. An arrangement is applied by which the cages gradually close the valve at the termination of each lift, and thereby ensure a soft and gradual cessation of the motion; and a safety apparatus is attached to each cage, to arrest its fall by gripping the guide bars in the event of the breakage of a chain.

Illustrations of the application of water power to machines of this class might be greatly multiplied. In all however the leading features and principles would be the same, and the new examples would merely show modifications of the same general mechanical arrangement.

The Chairman observed that the transmission of power by water pressure was a comparatively new branch of mechanical engineering, and not many years ago it had been doubted how far such an application of power could be brought to a successful issue. The principle however had gradually been more and more developed, chiefly owing to the energy and perseverance of the author of the

paper just read, who was unfortunately prevented from being present at the meeting. In almost every instance in which water pressure had been adopted it had been found one of the simplest and most complete methods of transmitting power, particularly in its application to cranes and hoists; and the adaptations of the principle to a variety of mechanical purposes appeared likely to increase continually in usefulness. As the water pressure machinery was now so largely adopted on wharves and in other exposed situations, he enquired whether much inconvenience had been experienced from the freezing of the water in the pipes and in the cylinders during severe weather.

Mr. G. Hutchinson, who attended the meeting in the absence of Sir William Armstrong, replied that there had been some few cases of cylinders being burst by the freezing of the water, but these had been very few indeed; out of as many as 5000 or 6000 hydraulic cylinders now in use in various parts of this country and abroad, there had been only six or eight instances he believed of cylinders being broken by the frost. As a precaution against such accidents, it was general to introduce a jet of gas into the chamber in which the hydraulic cylinders were placed; and even in a large chamber a very small jet of gas was found sufficient to prevent the water freezing. Where the cylinders were unavoidably exposed to the frost, without being covered in, it was necessary to provide means of draining them empty whenever they had to be left standing; because if the ram happened ever to be out to the full extent of its stroke, and the water were then to freeze, it would be almost certain to burst the cylinder, the ram being prevented by stops from moving any further. Of course if the ram were not at the end of its stroke it would yield to the expansion of the water in freezing, and so save the cylinder from being burst; and therefore if no means of draining the cylinder were provided, it was necessary in such cases to take care that the machine was never left standing with the ram fully out.

Mr. E. A. Cowper enquired whether a mixture of methylated spirit with the water had been tried for preventing the water from freezing. He knew a mixture of 5 per cent. of methylated spirit had been employed in similar cases, and had been found very effectual

for the purpose, as that proportion of spirit was quite sufficient to prevent water from freezing with any degree of cold ordinarily experienced in this country. In some of the oil mills at Hull the hydraulic presses were worked entirely with oil instead of water.

Mr. HUTCHINSON said it was not usual to employ a mixture of methylated spirit, although there were a few instances in which it had been adopted. One case in particular was that of a hydraulic drawbridge on the South Wales Railway near Carmarthen, constructed sixteen or eighteen years ago, and the spirit mixed with the water was found to have the desired effect in preventing freezing; the bridge was lifted and drawn backwards and forwards by water pumped into an accumulator by hand labour. That was the only instance however in which the plan had been used for a bridge, as in bridges generally the hydraulic machinery was either sufficiently well protected from frost, or else a gas jet was introduced into the chamber containing the water cylinders. With regard to the use of oil, it was employed in working the hydraulic cranes at the North Eastern Railway station at Hull, but only in a small quantity mixed with the water, for the purpose of better lubricating the slide-valve faces.

The CHAIRMAN enquired what kind of packing was generally used for the rams and pistons of the hydraulic machinery; whether it was hemp packing or cupped leathers.

Mr. HUTCHINSON replied that for the packing of rams generally it was preferred to use hemp; for although in the first instance the hemp produced considerably more friction than a cupped leather would do, yet when once consolidated a hemp packing worked with very little friction and was very durable. But for packing pistons in cylinders of double power, cupped leathers were preferable, on account of the difficulty of getting at the piston to screw up a hemp packing or renew the packing when necessary; whereas with a ram there was only the external stuffing-box to be packed, which was easily accomplished at any time. Another objection to a hemp packing for pistons was that the strands of hemp, especially when new, were partially worn off in the process of working, and the loose bits of hemp getting into the valves were liable to foul them, causing

leakage and other inconveniences. For these reasons cupped leathers were generally used for the packing of pistons, except where a hemp packing was particularly desired; but for the rams hemp packing was invariably employed.

Mr. E. A. Cowper considered they were greatly indebted for the valuable details given in the paper respecting the successful working of the hydraulic machinery; and he fully concurred in the advantages that would result from conveying power by means of water pressure to a great distance; the successful application of the plan to a distance as great as two miles was a practical result of great importance. In comparing water with air as a medium for the transmission of power, it must be admitted that air was exceedingly useful for conveying the power required to work coal-cutting or tunnelling machines, where it would be impossible with water to obtain anything like 200 to 300 strokes per minute of the tool, on account of the entire absence of elasticity. But on the other hand the use of air was attended with several disadvantages, the most important of which was perhaps the amount of leakage that took place without being detected, as mentioned in the paper. There was also another inevitable source of loss with air, which had not been referred to; and this was that in the compression of the air the large amount of heat developed by the compressing engine was all dissipated and lost before the compressed air reached the point of application, so that the actual volume of air was less after it had traversed the length of the connecting pipes than in the compressing engine, in addition to which the air cooled in expanding. Besides this, in compressing there was the resistance of the full compression figure against the engine, whilst in using the compressed air it was impossible to obtain the full value of the expansion figure; and an indicator diagram taken from the machine worked by the compressed air would show a considerably smaller amount of power than the corresponding diagram from the air-compressing cylinder, thus proving a proportionate loss of power in the use of the compressed air. Air however, particularly in a cool and perfectly fresh state, was of the greatest value in mines and tunnels; and in these and some other cases was much to be preferred to water

power. It would therefore be required to be determined for each separate case of transmitting power to a distance, whether the advantages preponderated in favour of air, or whether water was better adapted for the purpose in view.

The advantages of employing water pressure for conveying power to considerable distances he had himself realised many years ago in the case of a forge, having adopted that plan for working a number of different machines used in the manufacture of iron, for pressing, bending, and punching, &c.; and there was no doubt a great advantage also in the extremely steady motion that was obtained by the use of water. As a simple and compact form of reservoir for giving the required pressure he had employed a cylinder fitted with a vertical differential ram, working through stuffing-boxes at top and bottom, and loaded with a weight sufficient to produce the pressure needed; the upper half of the length of the ram was 4 inches diameter and the lower half 3 inches diameter, the length of stroke being about 10 feet. An engine was kept constantly pumping water into this reservoir, and the quantity of water accumulated under pressure by this means was found quite sufficient to work a number of different machines situated in various parts of the works. This was the method employed for working a very large punching press used in punching out the flat links for the Kief suspension bridge in Russia; the links were each 10 inches by 1 inch in the body, and had one large eye at one end and a long slot for adjusting keys at the other, and were 7 feet 6 inches long and about 17 inches over the eyes; the whole was punched hot out of a large plate in about 3 seconds by one stroke of the press, on simply turning a cock to admit the water pressure. The idea of accumulating the pressure in a reservoir in this manner had been suggested to him by seeing the plan adopted in a paper mill, where it was the practice to save the trouble of charging independently each of the hydraulic presses employed for pressing the paper, by connecting all the presses with one loaded press, and using this as an accumulator for storing water, keeping it constantly charged by the pumps, ready for working the other presses; by this arrangement the convenience of an accumulator was obtained for working the other presses. A valuable description had been

given in the paper of a variety of applications of water pressure for lifting weights; and another purpose, for which it was peculiarly well adapted, was the testing of girders, where the steadiness of motion obtained was of great value in arriving at accurate results.

Mr. F. W. Webb enquired with regard to the hydraulic lift for blast furnaces, whether there was any communication between the two hydraulic cylinders working the hoist, in order to make them always work simultaneously, so as to avoid any risk of disarranging the wire rope connecting the two cages of the hoist, by starting one cylinder before the other.

Mr. Hutchinson explained that both the cylinders were controlled in conjunction by a single handle, which worked an ordinary three-port slide-valve, like the slide-valve of a steam engine; so that when the pressure was admitted to one of the cylinders, the other was at the same time opened to the exhaust.

The Chairman enquired what was the greatest height to which the blast-furnace hoist had been made to lift.

Mr. Hutchinson replied that the highest hoist which had been made was for some blast furnaces at Ferryhill, where the height of lift was 102 feet. The hoist shown in the drawings was for a lift of 80 feet height.

Mr. W. Clay remarked that, having had to design some rather powerful hydraulic machinery for the Mersey Iron Works, Liverpool, he had introduced some arrangements which he had not met with elsewhere in the employment of water pressure. There were two lifts of 20 and 30 feet height for raising materials at the works, each capable of lifting a load of 20 tons; and the siding along which the wagons were brought to one of the lifts being at an angle of 30° to the line of rails at the upper level, the circular platform of the lift, 20 feet in diameter, was turned round through the angle of 30° during its ascent or descent, by a rifle motion giving it a spiral movement in rising or falling, so that the lift itself acted as a turntable, instead of requiring a separate turntable on the platform of the lift.

It had also occurred to him that, if the weight of the descending loads on the lifts could be utilised, a saving would be effected of

nearly half the power otherwise required for working the lifts. For as the accumulator working the lifts had to be weighted to a pressure of 600 lbs. per square inch for raising a load of 20 tons on the lift, there would be a loss of 300 lbs. of pressure at each time of lowering an empty wagon of 10 tons weight. In order therefore to turn to advantage the pressure exerted by the descending loads, it was only necessary to open a communication between the cylinders of the descending lifts and the suction pipe of the double-acting pumps charging the accumulator, instead of running the water from the lifts into an open reservoir as was usually done; by this means the pressure due to the descending load, whatever it might be, was utilised in assisting the pumps to charge the accumulator. For example, in the case of lowering a wagon of 10 tons weight, representing a pressure of say 300 lbs. per square inch, the valve was opened admitting the water at a pressure of 300 lbs. per square inch from the lift to the pumps, thus assisting them to that extent in charging the accumulator which was weighted to 600 lbs. per square inch, and thereby saving the use of one half the steam power otherwise required. The result of this arrangement was that, instead of requiring 45 lbs. steam to work the engine for charging the accumulator, a steam pressure of only 25 lbs. was found sufficient for keeping it charged; and although there would have been a deficiency of boiler power for working the lifts, according to the usual plan of running to waste all the water discharged in lowering, yet by this method of utilising the effect of the descending loads there was always an ample supply of steam maintained for keeping the accumulator fully charged, the steam engine having in fact only half the work to do. There was of course some little difficulty in the application of this plan in cases where a number of cranes or lifts were all connected to the same discharge pipe, because if a heavy load were being lowered, a lighter one would have to wait and could not begin to descend till the heavier one had reached the bottom, since the cylinders of the two descending lifts would at that time be put in communication with each other through the discharge pipe. Moreover the lighter loads would be retarded in their descent as compared with the heavier ones, because the rate at which the pumps worked and took

the water from the descending lift limited the speed of descent; and that rate would be slower when less aid was given by a lighter load. Provision was also made by suitable valves for turning the water from the descending lifts into an open reservoir in the usual manner, if desirable at any time.

This arrangement had proved so successful in economising power, that he had applied the same plan also to the hydraulic machinery employed in the Bessemer works at the same place, in the original designing of which there had not been sufficient power provided for working all the cranes for the ladles and moulds with the required rapidity, and it had been found that the casting pits could not be cleared quickly enough to get through all the work that had to be done. By adopting this simple method however of utilising all the descending weights, he had now obtained power enough for the work required; and the whole cost of the alterations made for the purpose had been very trifling.

Mr. Hutchinson said that the principle of utilising the weight of a descending load had been applied for several years past in the hydraulic machinery used for loading coals into ships, where the coal was delivered alongside at a high level and had to be lowered down into the ships to a depth of perhaps 50 or 60 feet. An instance of this sort was to be seen at Newport in Monmouthshire, where each box containing about 2 tons of coal was first lifted clear off the truck by a hydraulic cylinder of very short range but considerable diameter, and was then allowed to descend by its own weight; by its descent a ram of small diameter was forced back against the pressure of the accumulator, but when the coal had been discharged, the ram had sufficient power to raise the empty box again. In other cases, such as hoists for lifting wagons, where it was desired to economise power, a small auxiliary ram was employed, which was forced back against the accumulator pressure by the descent of the empty hoist; or else a counterbalance weight was used, not quite as heavy as the cradle of the hoist.

The idea of turning round the platform of a hoist during its ascent and descent had been carried out some years ago in two hoists at Grimsby. In these hoists two vertical guides were used,

with oblique grooves cast upon their inner faces, so that the face of the guide would represent a segment cut out of a long spirally-rifled cylinder; and corresponding oblique teeth fitted round the circumference of the circular platform made the platform twist round in ascending and descending, by sliding in the rifle grooves.

Mr. E. Howard enquired what was the minimum pressure of water at which the hydraulic cranes and other machines were found to work satisfactorily; there must of course be a certain amount of pressure necessary to overcome the friction.

Mr. Hutchinson replied that hydraulic cranes had been made to work at as low a pressure as only 40 to 50 lbs. per square inch, but in those cases the cylinders were necessarily very large and very expensive, particularly if the load to be lifted was considerable or the height of lift great. Where the pressure had to be produced artificially by the aid of an accumulator, it had been found in general that the pressure named in the paper, of 700 lbs. per square inch, was the most convenient. In some instances the pressure had been increased up to 1000 lbs. per square inch, as in the case of the chain-testing works at Birkenhead, where that pressure had been adopted for four hoists employed for loading vessels, and originally isolated from the rest of the works. Subsequently however considerable inconvenience had arisen in consequence; for the hydraulic machinery in the rest of the works having been extended, at the more usual pressure of 700 lbs., it had now become necessary to combine the two systems, and much difficulty and trouble had been occasioned from having to deal with two different pressures. The principal objection that had been experienced in going to a higher pressure than 700 lbs. was that the rams and their attachments became then inconveniently small. A certain diameter and width of groove was necessary for the sheaves, to suit the size of the chains employed, and a proportionate size of pin and area of rubbing surface was required to ensure durability; the crosshead therefore had to be made not less than a certain size, and this involved also a certain minimum diameter for the ram. The same objection as to the size of the parts did not apply to reducing the working pressure somewhat below the standard of 700 lbs., and in

some cases hydraulic machinery had been constructed for a pressure of 500 lbs. per square inch, and worked at that pressure without inconvenience. At the London Docks a pressure of 600 lbs. had been adopted in the first instance; but a second set of machinery having afterwards been put down at some distance with the higher pressure of 700 lbs., the subsequent combination of the two pressures had proved very inconvenient. On these accounts therefore 700 lbs. per square inch had been decided upon as the standard pressure for all hydraulic machinery, and was now invariably employed.

Mr. F. J. Bramwell mentioned that a low-pressure hydraulic hoist had been put up at the new Westminster Palace Hotel, which was worked by the pressure of water from a tank at the top of the hoist, the pressure being equal to about 35 to 40 lbs. per square inch; and the tank was supplied with water from the ordinary street main. The piston of the hoist was 20 inches diameter with 10 feet stroke, and the height of lift was about 56 feet; the stroke of the piston was multiplied $5\frac{1}{2}$ times to equal that of the lift, by means of a rack working a pinion on the shaft of a large pulley. The cost of the water was said to be 1*d.* per lift for the full height.

With respect to the question of transmitting power from a common central source to a number of cranes, it might be mentioned that as long ago as the opening of the St. Katherine's Docks in London it was intended to employ the pneumatic or exhaustion system for working the cranes, by means of engines attached to them and driven by the pressure of the atmosphere working against a partial vacuum, the connection to the central motive power being effected by exhaust mains; but a long delay that occurred in the construction of the trial crane led to the abandonment of the system at those docks, as the common cranes had in the meantime been fixed. The exhaustion system was useful under certain circumstances and had been extensively applied in a variety of ingenious ways; there were however objections to it, one of which was the small pressure per inch that could be obtained on the working pistons, and the consequent large diameter of the cylinders. This defect was increased if it were sought to work expansively; but without expansion there must clearly be a great loss of power in these cases,

as the exhausting air-pumps would show a figure like an expansion diagram and would require the power due to such a diagram for working them; and therefore if the pneumatic cylinders were not worked with an expansion curve practically corresponding with that of the exhausting pumps, a serious loss of power would ensue. For these reasons he did not think that for general purposes the pneumatic or exhaustion system would ever successfully compete with the use of water pressure for the transmission of power; and in the great majority of cases where power had to be transmitted from a distance, water pressure was decidedly superior to the use of air whether by exhaustion or compression. In the particular instance however of working underground machinery, as in collieries, air had the advantage of answering the double purpose of conveying power to a distance and of aiding in the ventilation of the workings; in such situations also the discharge of water from hydraulic machinery might be very undesirable.

Mr. R. Mallet observed that it was a remarkable circumstance that Bramah, the inventor of the hydraulic press, had suggested as early as 1802 the application of the same principle for working the cranes on the dock quays at Dublin and in the warehouses of the London Docks, as was shown by the accompanying autograph letter.* This showed that Bramah had distinctly seen the great scope for

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* Extract from autograph letter of Joseph Bramah to Robert Mallet, dated London 10 Nov. 1802, the original of which was shown to the Meeting and a photographic duplicate presented:—

"I have also now applied it" (the Hydraulic Press) "with the most "surprising effect to every sort of crane for raising and lowering goods in and "out of warehouses. So complete is the device, that I will engage to erect a "steam engine in any part of Dublin, and from it convey motion and power to "all the cranes on the keys and elsewhere, by which goods of any weight may "be raised at one third of the usual cost. This I do by the simple communication "of a pipe, just the same as I should do to supply such premises with water. I "have a crane on my own premises which astonishes every person to whom it "has been shown, as they see the goods ascend and descend 15 or 20 times in a "minute to the height of 18 or 20 feet, and at the same time it is impossible for "any person unacquainted with the principle to discover how or where the "power comes from."

future expansion of the principle; but he had been too much in advance of the time for his ideas to be practically developed during his lifetime to so great an extent as they had since been by the very ingenious and perfect arrangements described in the paper now read.

The CHAIRMAN remarked that unquestionably the principle of Bramah's hydraulic press, which had gained a world-wide fame, formed the basis of the present applications of water pressure; but it was only within the last few years that the employment of water pressure had been systematically worked out as a means for the transmission of power.

He moved a vote of thanks to Sir William Armstrong for his paper, which was passed, and also to Mr. Hutchinson for the additional explanations which he had given.

A paper was then read "On the Allen Engine and Governor," by Mr. Charles T. Porter, of Manchester; and the discussion was adjourned to the next meeting. (See Proceedings April 1868.)

The Meeting then terminated; and in the evening a number of the Members dined together in celebration of the Twenty-first Anniversary of the Institution.

ALLEN ENGINE AND GOVERNOR.

Fig. 1. *Side Elevation. with Section of Air-pump.*

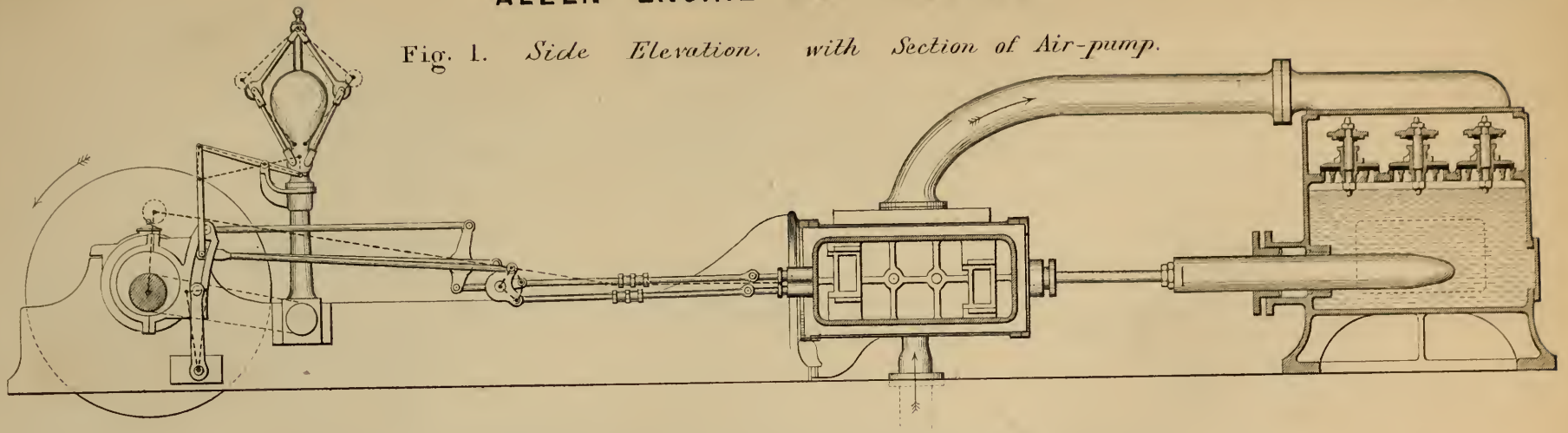
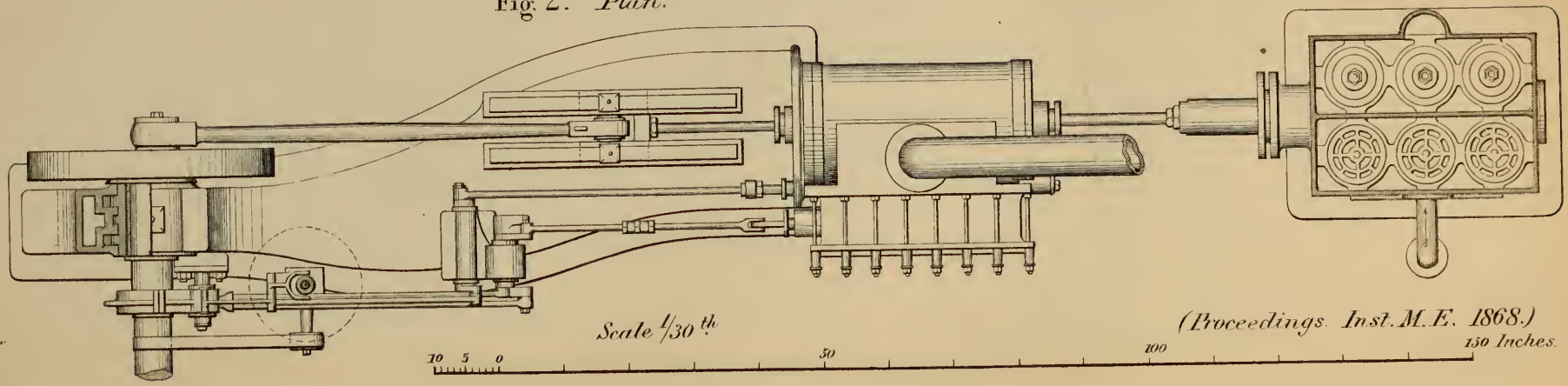


Fig. 2. *Plan.*



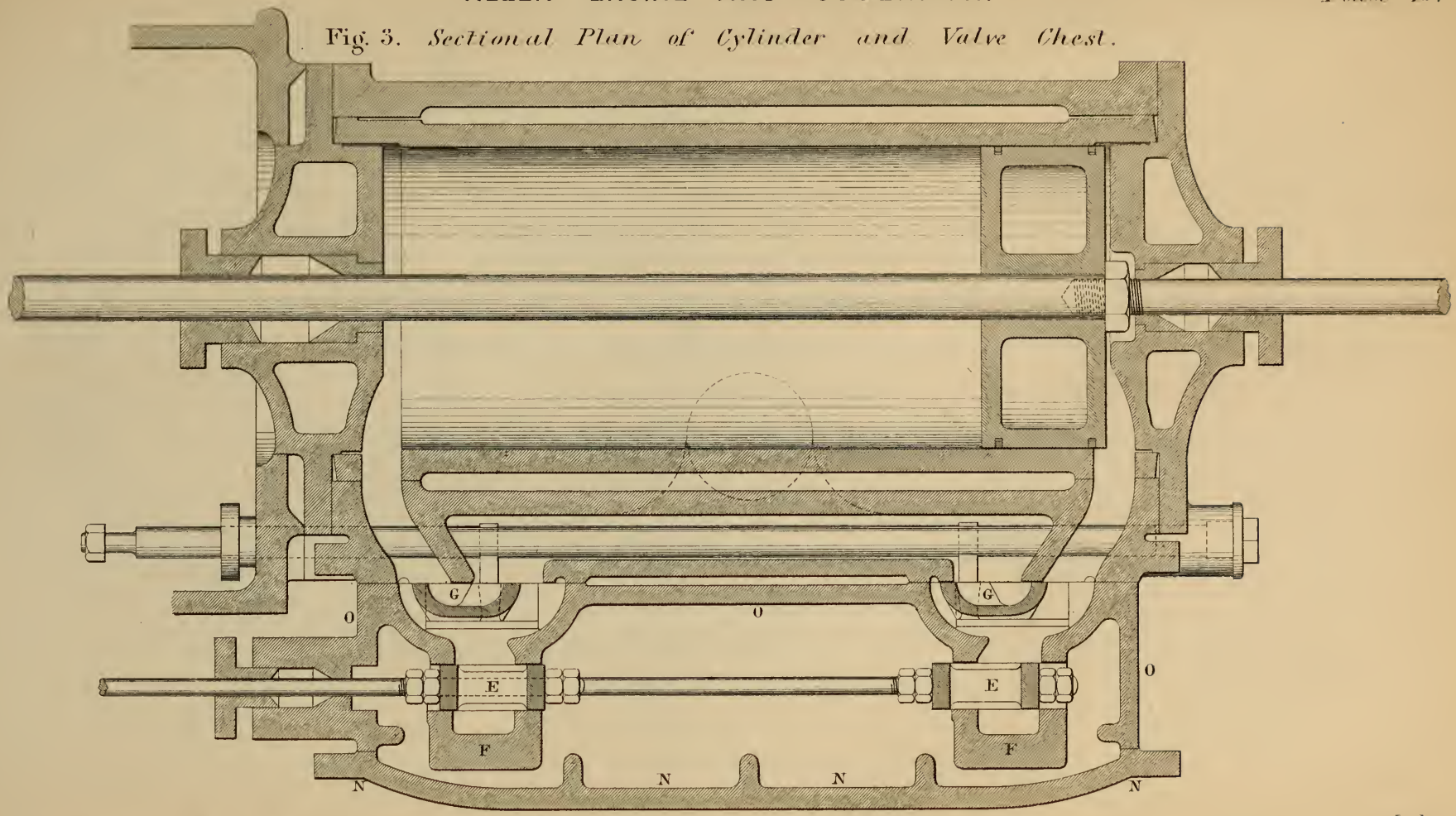
Scale 1/30th

10 5 0 50 100 150 Inches.

(Proceedings. Inst. M.E. 1868.)

ALLEN ENGINE AND GOVERNOR.

Fig. 3. *Sectional Plan of Cylinder and Valve Chest.*



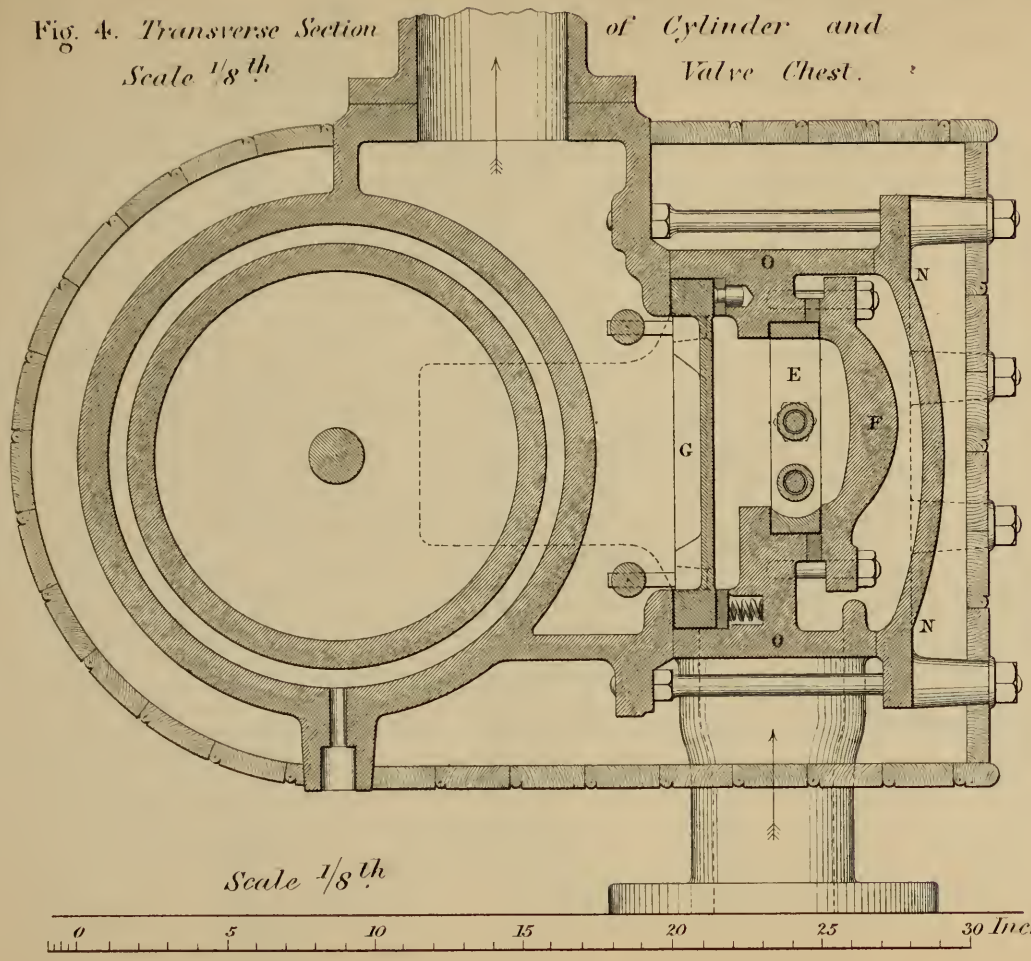
(Proceedings Inst. M. E. 1868.) *Scale 1/8th*

ALLEN ENGINE AND GOVERNOR.

Plate II.

Fig. 4. *Transverse Section of Cylinder and Valve Chest.*

Scale 1/8th



Scale 1/8th

0 5 10 15 20 25 30 *Inches.*

Elevations of Port Faces.

Scale 1/16th

Fig. 5. *Steam Ports.*

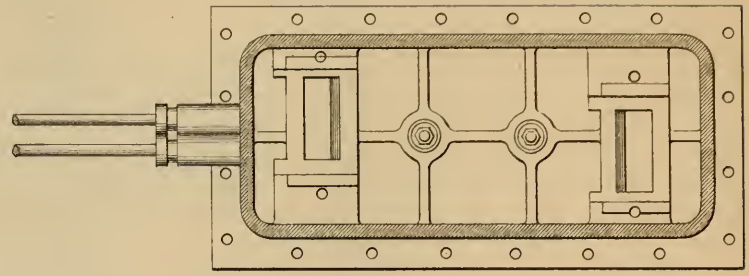
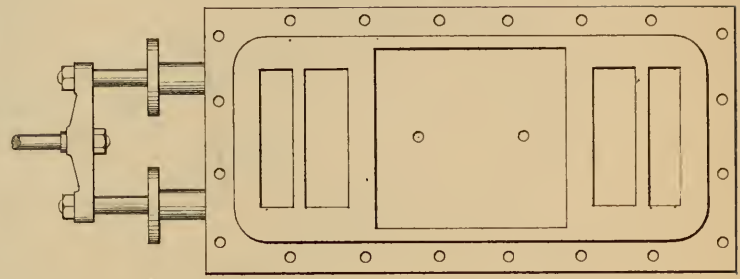


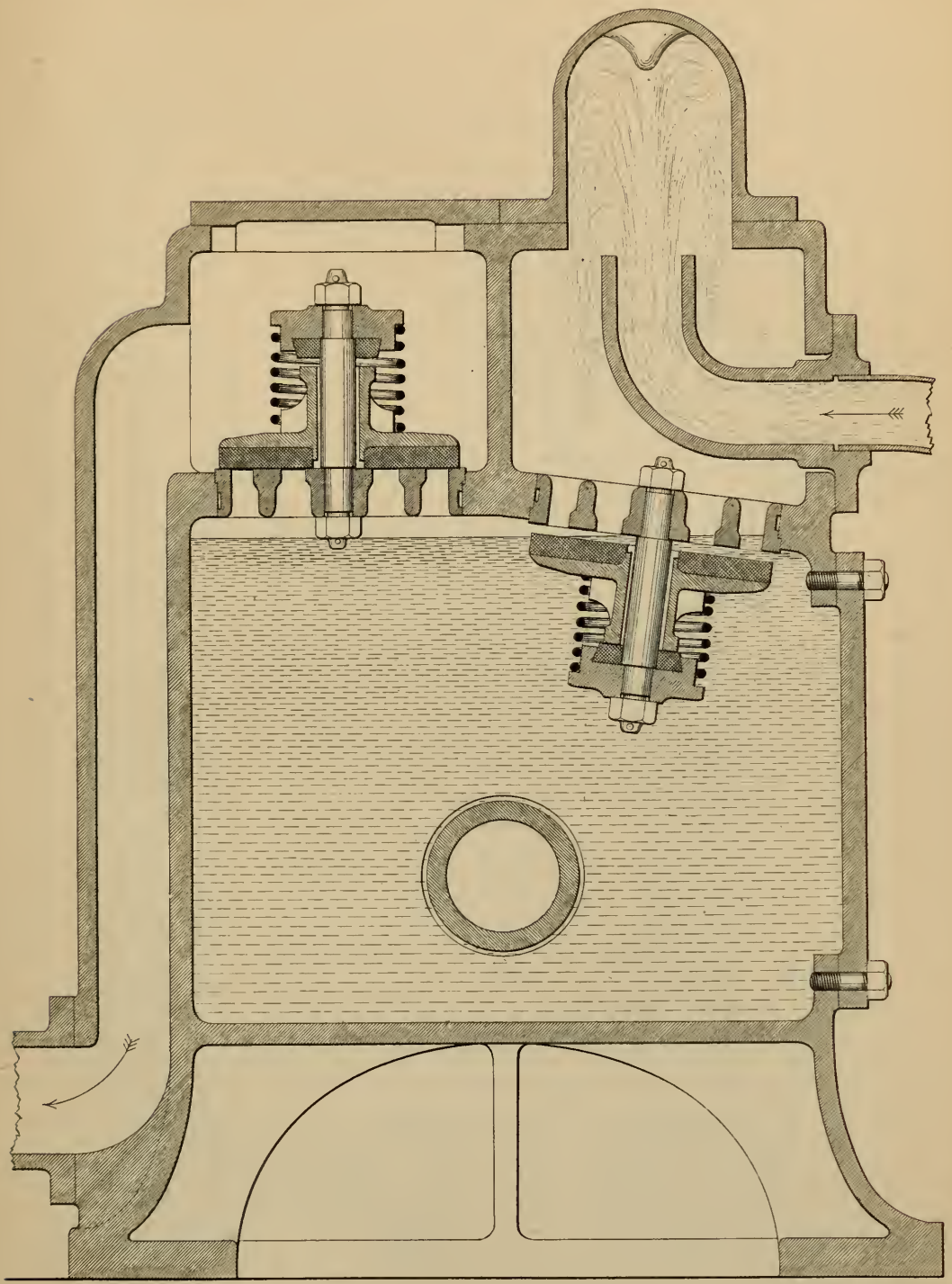
Fig. 6. *Exhaust Ports.*



Scale 1/16th

(Proceedings Inst. M.E. 1868.)

Fig. 7. *Transverse Section of Condenser and Air-pump.*



(Proceedings Inst. M.E. 1868)

Scale 1/8th

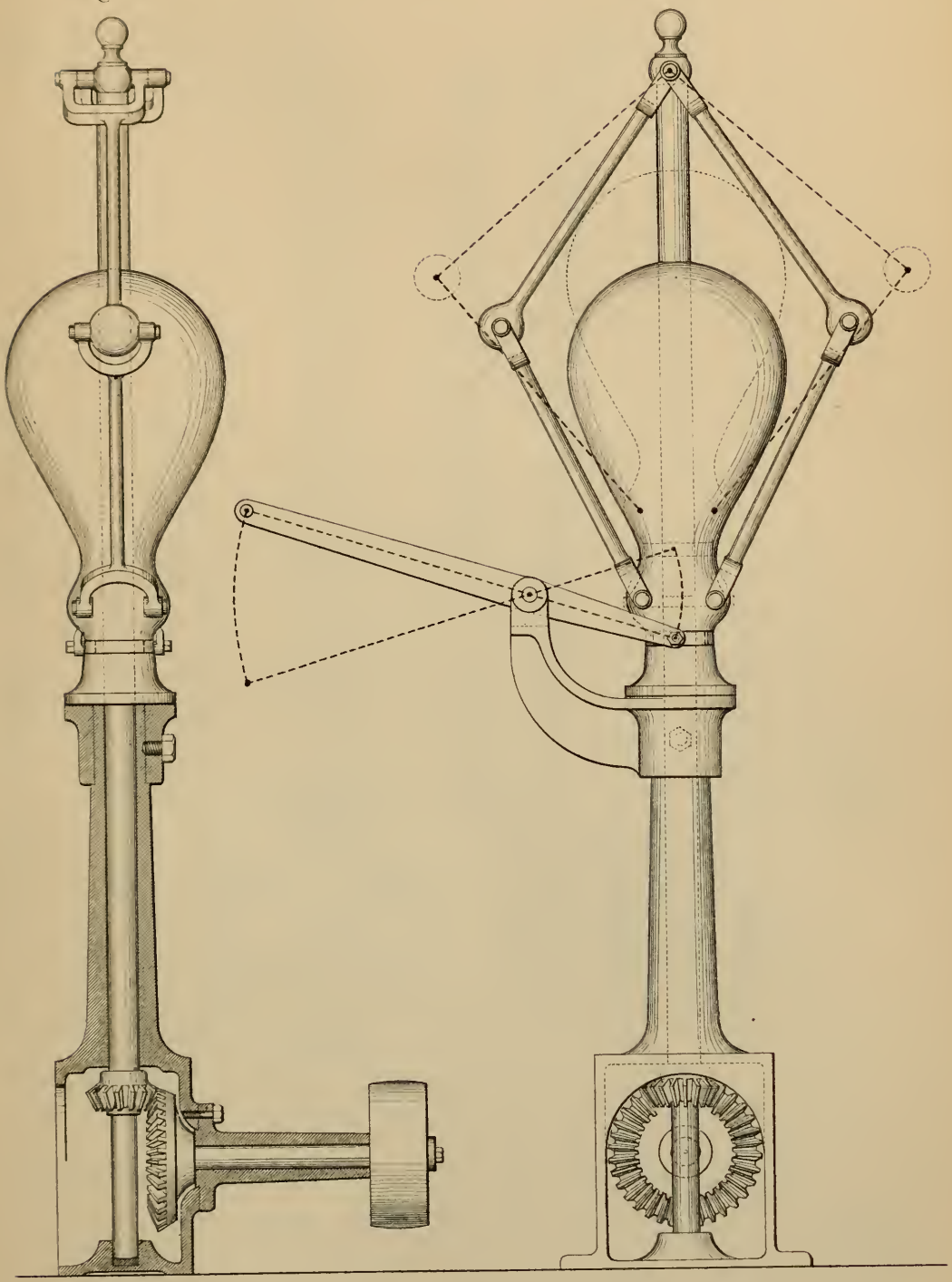
0 5 10 15 20 25 30 *Inches.*

ALLEN ENGINE AND GOVERNOR. *Plate 13.*

Elevations of Governor.

Fig. 8.

Fig. 9.



(Proceedings Inst. M.E. 1868)

Scale 1/8th

0 5 10 15 20 *Inches.*

ALLEN ENGINE AND GOVERNOR.

Plate 14.

Valve Gear.

Fig. 10.
Transverse Section.

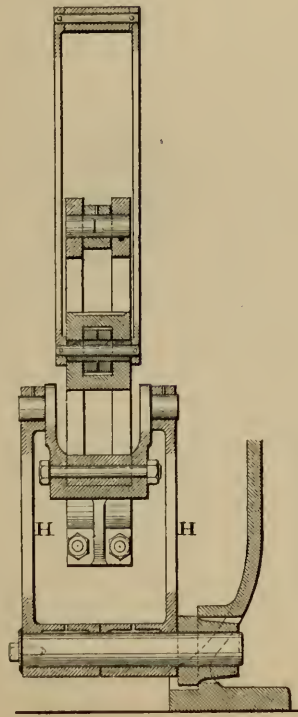


Fig. 11. *Plan.*

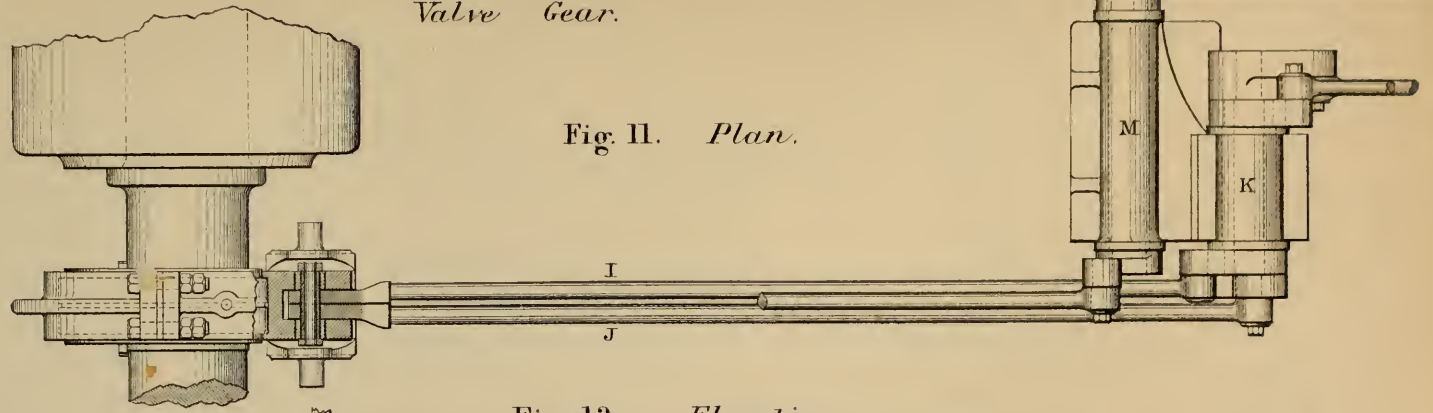
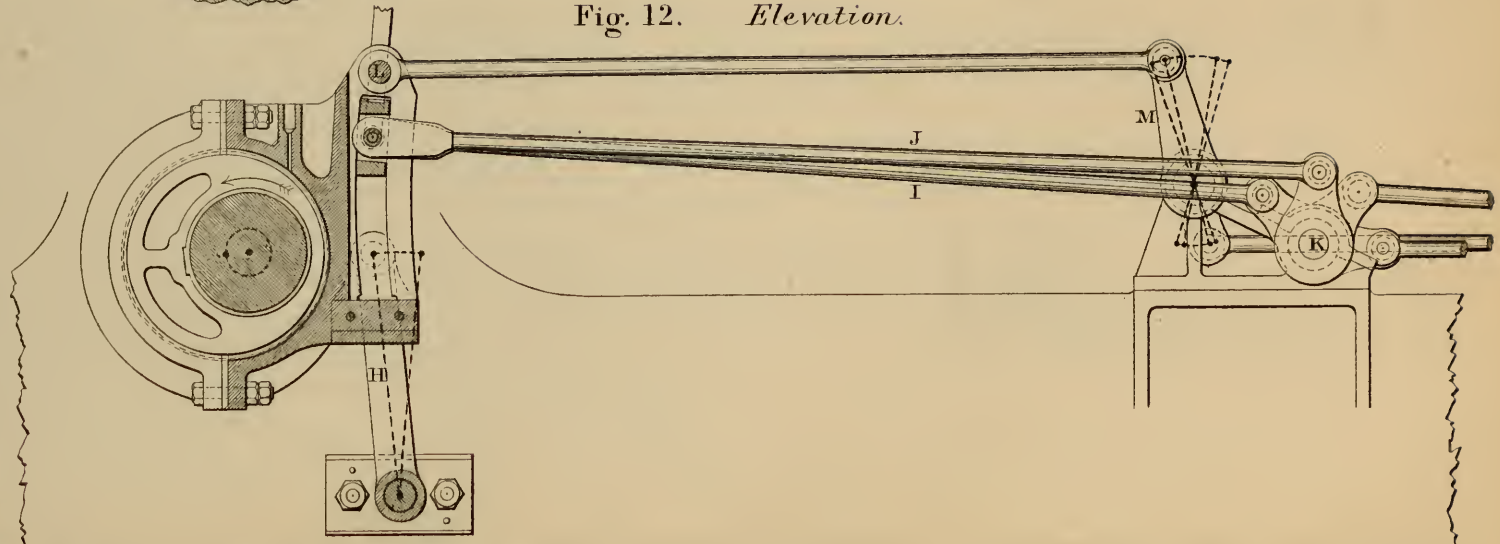


Fig. 12. *Elevation.*



(Proceedings Inst. M.E. 1868.) Scale 1/12 th

ALLEN ENGINE AND GOVERNOR.

Valve Motion,
the reference letters indicating corresponding positions throughout.

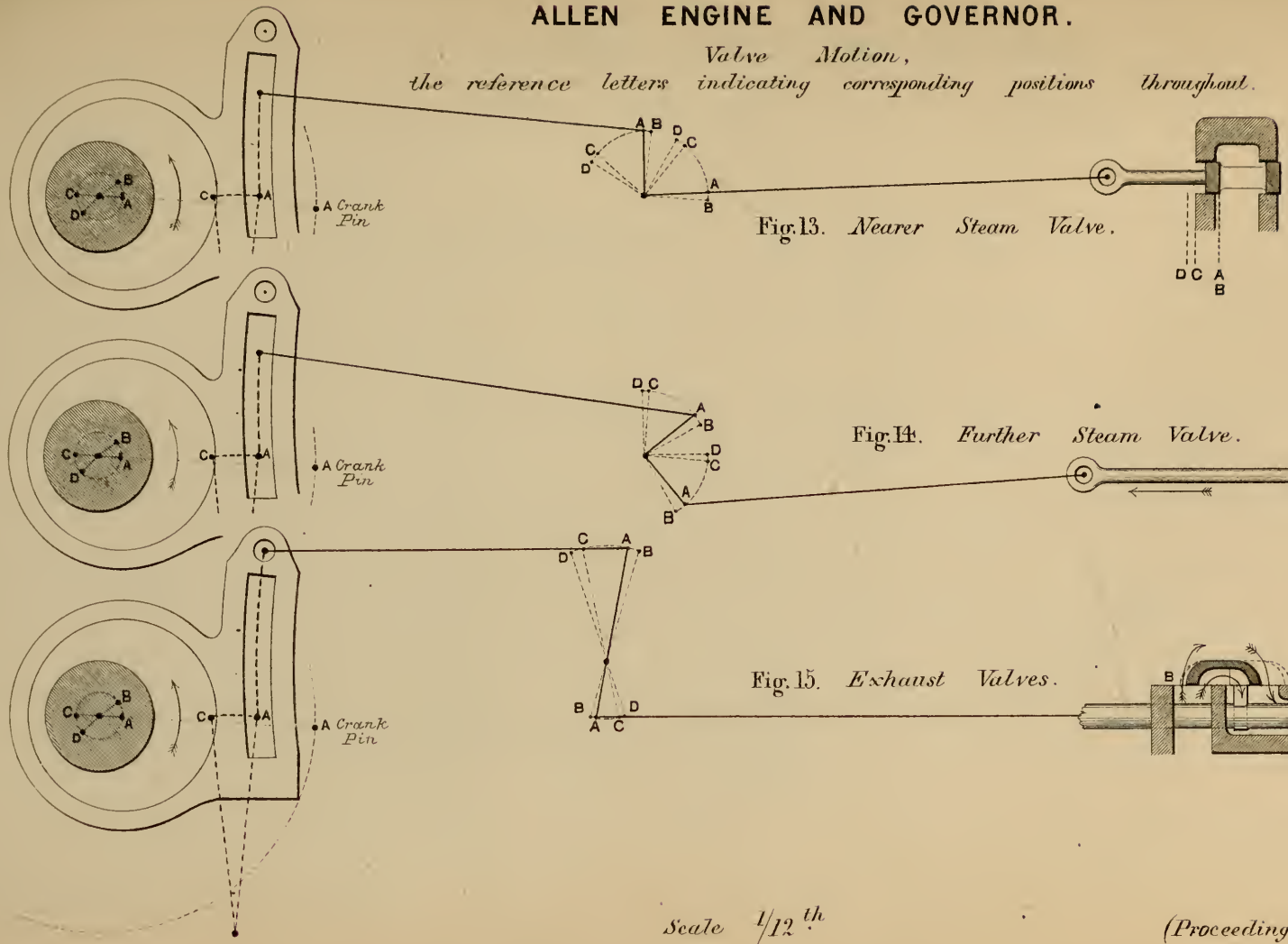


Fig. 13. *Nearer Steam Valve.*

Fig. 14. *Further Steam Valve.*

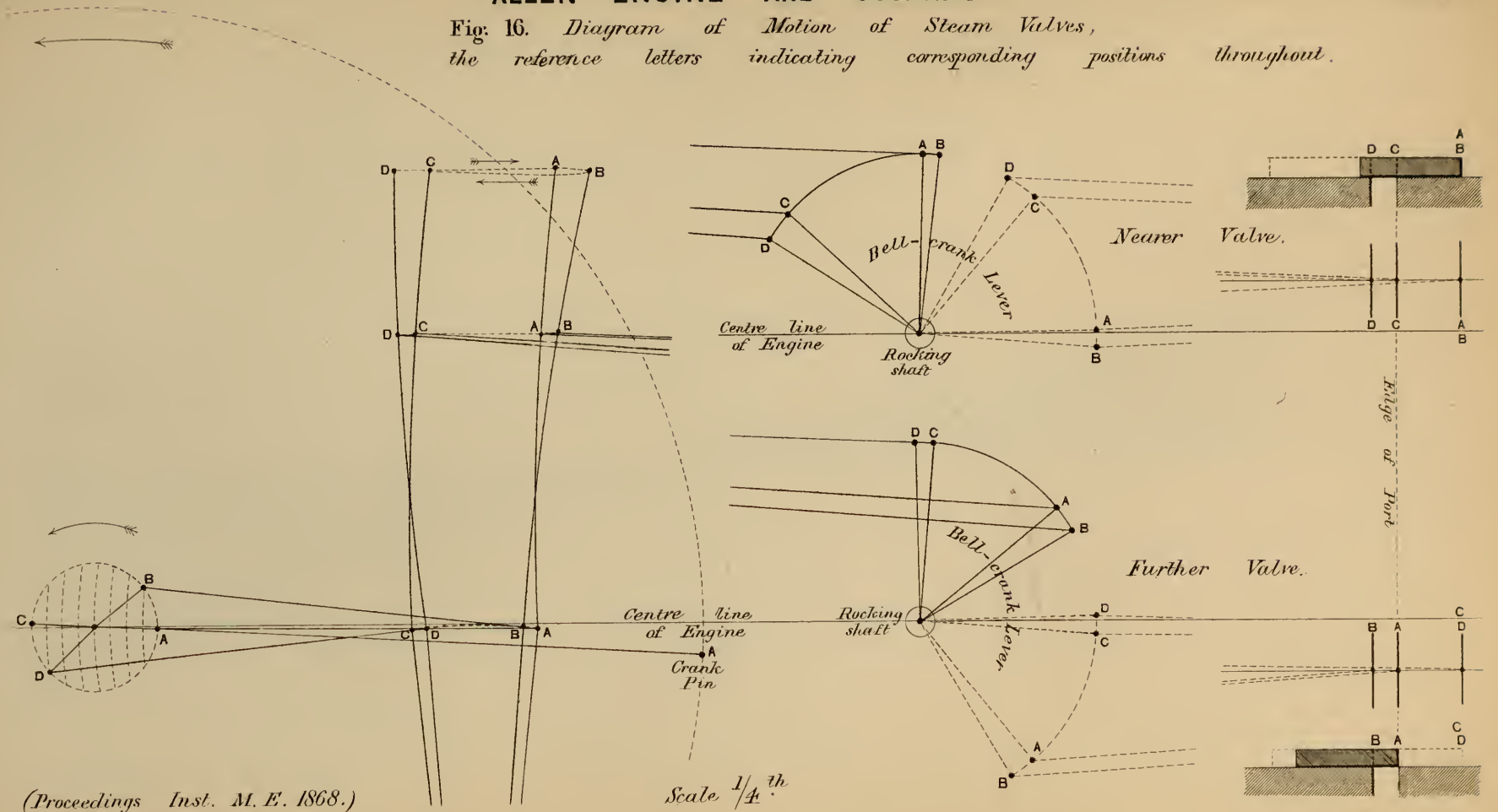
Fig. 15. *Exhaust Valves.*

Scale 1/12 th

(Proceedings Inst. M. E. 1868.)

ALLEN ENGINE AND GOVERNOR.

Fig. 16. *Diagram of Motion of Steam Valves, the reference letters indicating corresponding positions throughout.*

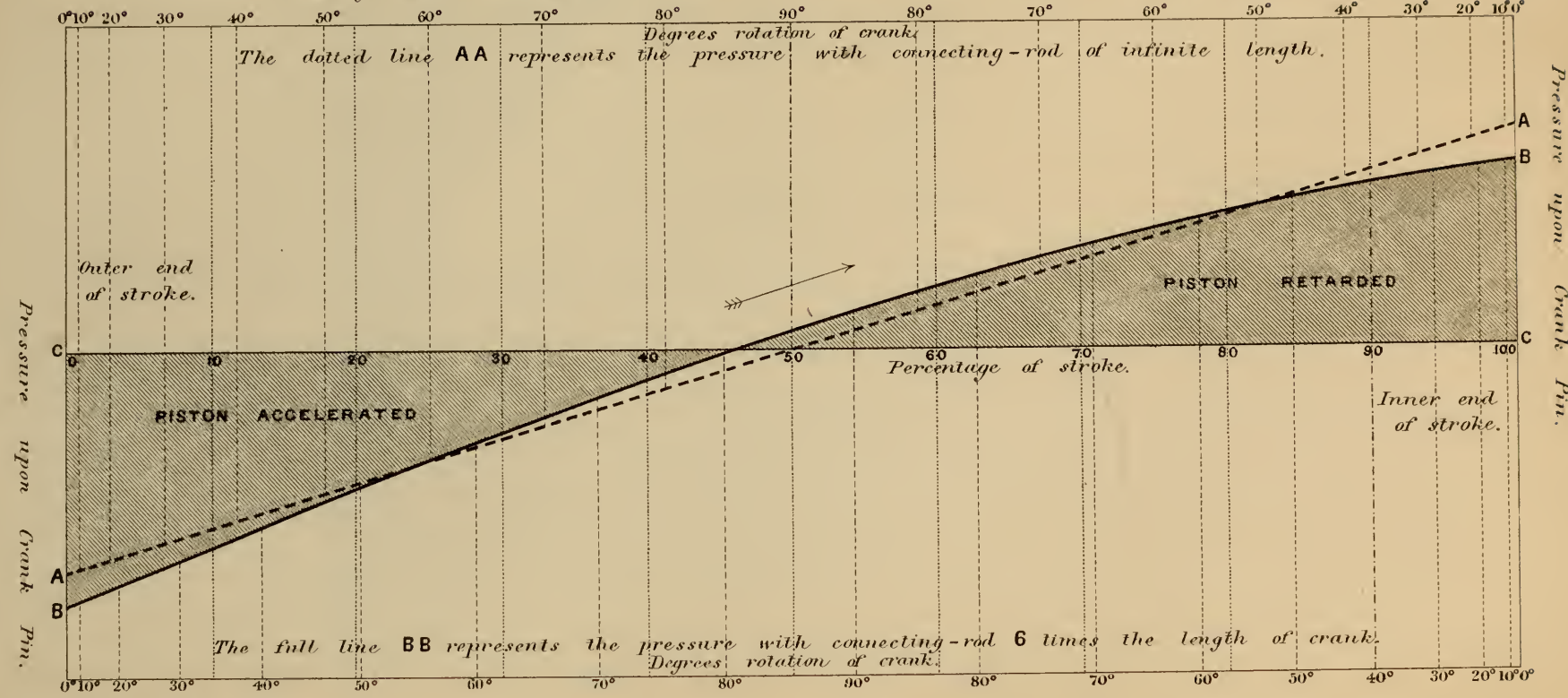


(*Proceedings Inst. M. E. 1868.*)

Scale 1/4th.

ALLEN ENGINE AND GOVERNOR.

Fig. 17. *Diagram showing Pressure upon Crank Pin, produced by the inertia of the horizontal reciprocating parts during their acceleration and retardation in each half of the stroke.*


0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0°
Degrees rotation of crank.
The dotted line AA represents the pressure with connecting-rod of infinite length.
Outer end of stroke.
PISTON RETARDED
PISTON ACCELERATED
C
0 10 20 30 40 50 60 70 80 90 100
Percentage of stroke.
Inner end of stroke.
A
B
Pressure upon Crank Pin.
The full line BB represents the pressure with connecting-rod 6 times the length of crank.
Degrees rotation of crank.
0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0°

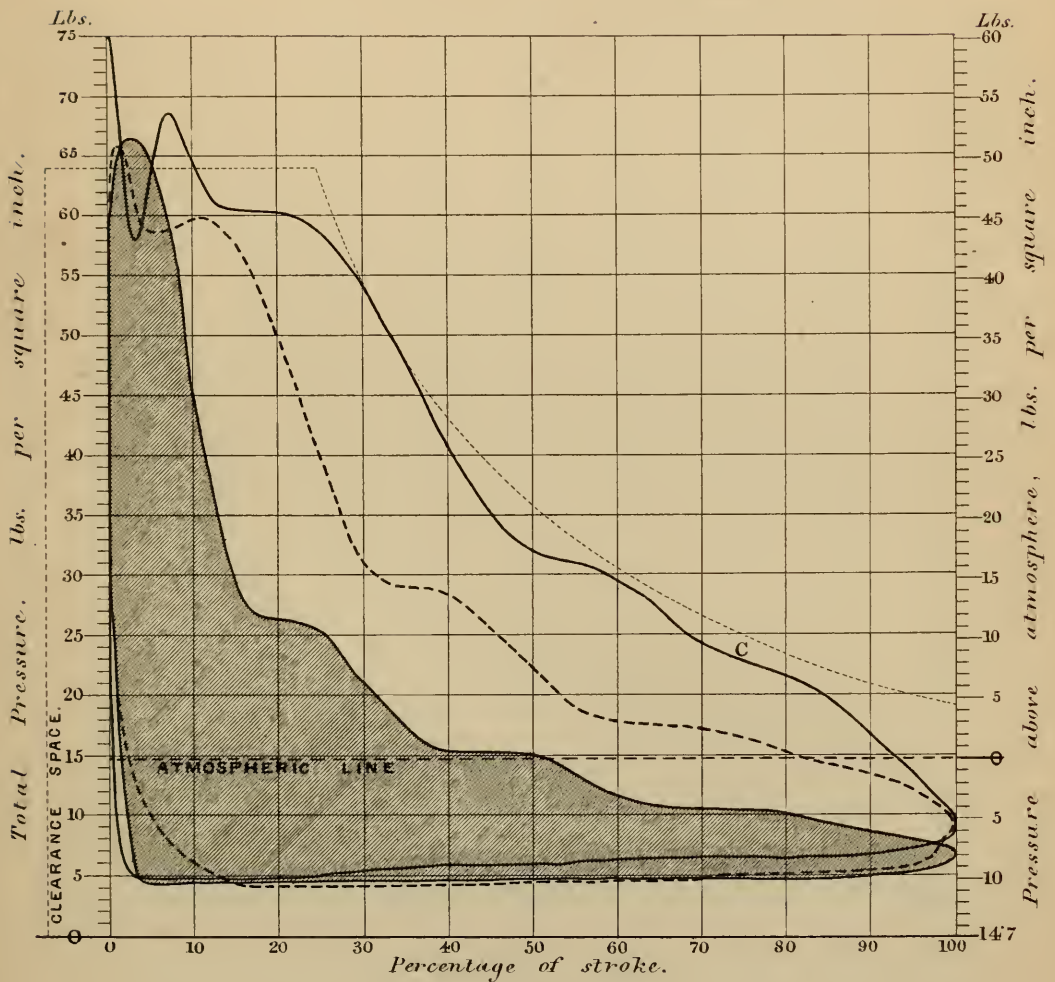
(Proceedings Inst. M.E. 1868.)

Fig. 18. *Indicator Diagrams from Allen Engine.*

Cylinder 12 *ins. diam.*, 24 *ins. stroke.*

200 *Revolutions per minute.*

Speed of Piston 800 *feet per minute.*



The fine dotted line shows the theoretical true expansion curve of the indicator diagram C.

(Proceedings Inst. M. E. 1868.)

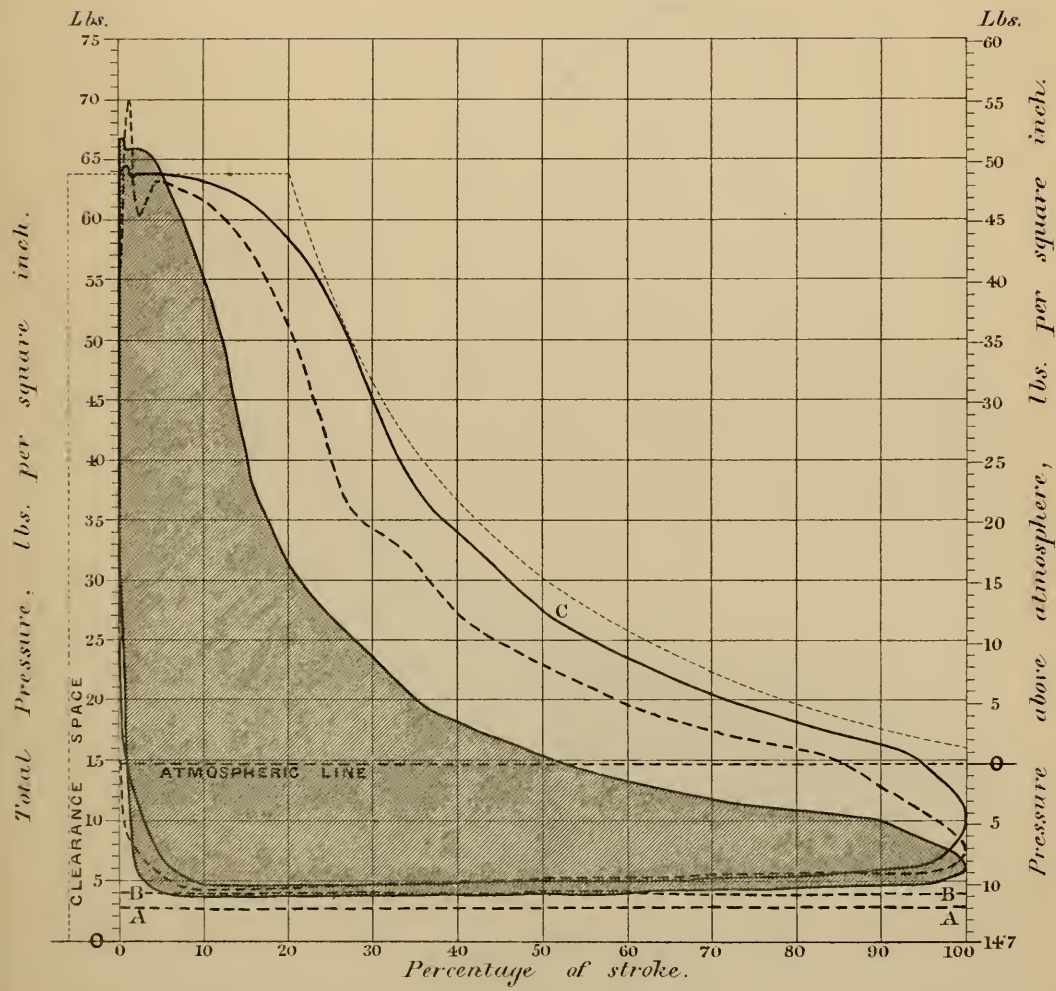
ALLEN ENGINE AND GOVERNOR. *Plate 19.*

Fig. 19. *Indicator Diagrams from Allen Engine.*

Cylinder 18 *ins. diam.,* 30 *ins. stroke.*

120 *Revolutions per minute.*

Speed of Piston 600 *feet per minute.*



AA *vacuum in condenser* } *at the time of taking the*
BB .. .. *exhaust chamber* } *dotted indicator diagram.*

The fine dotted line shows the theoretical true expansion curve of the indicator diagram C.

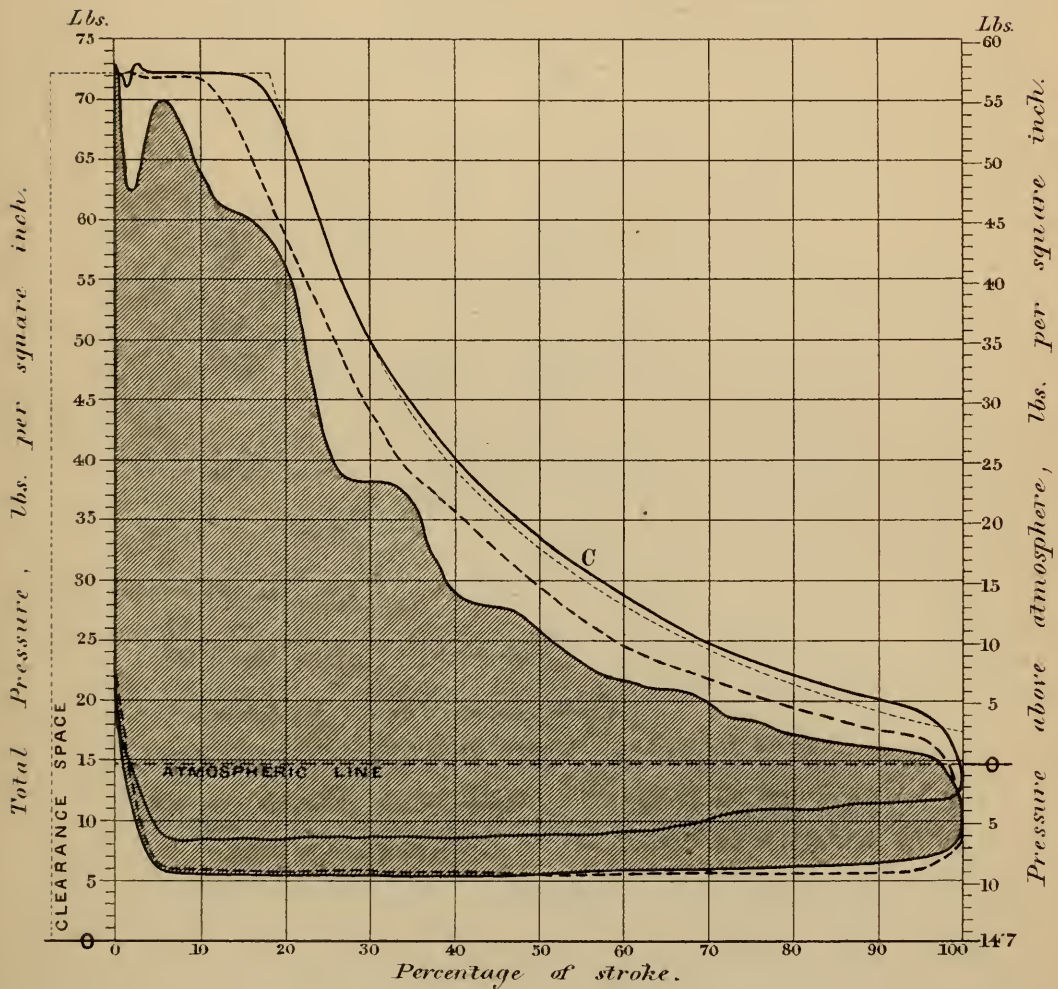
(Proceedings Inst. M. E. 1868.)

Fig. 20. *Indicator Diagrams from Allen Engine.*

Cylinder 20 *ins. diam.,* 36 *ins. stroke.*

100 *Revolutions per minute.*

Speed of Piston 600 *feet per minute.*



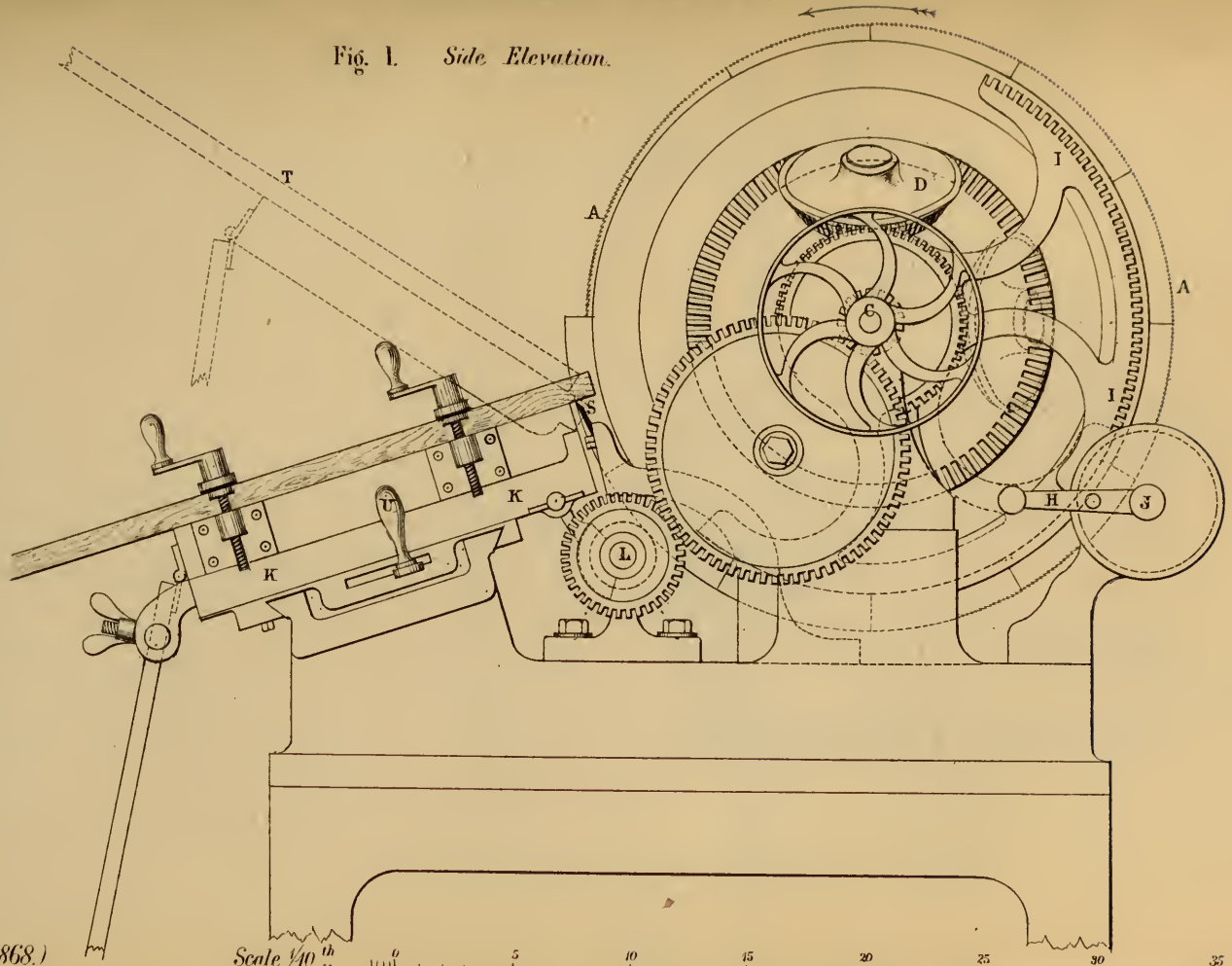
The fine dotted line shows the theoretical true expansion curve of the indicator diagram C.

(Proceedings Inst. M. E. 1868.)

DOVETAILING MACHINE.

Plate 21.

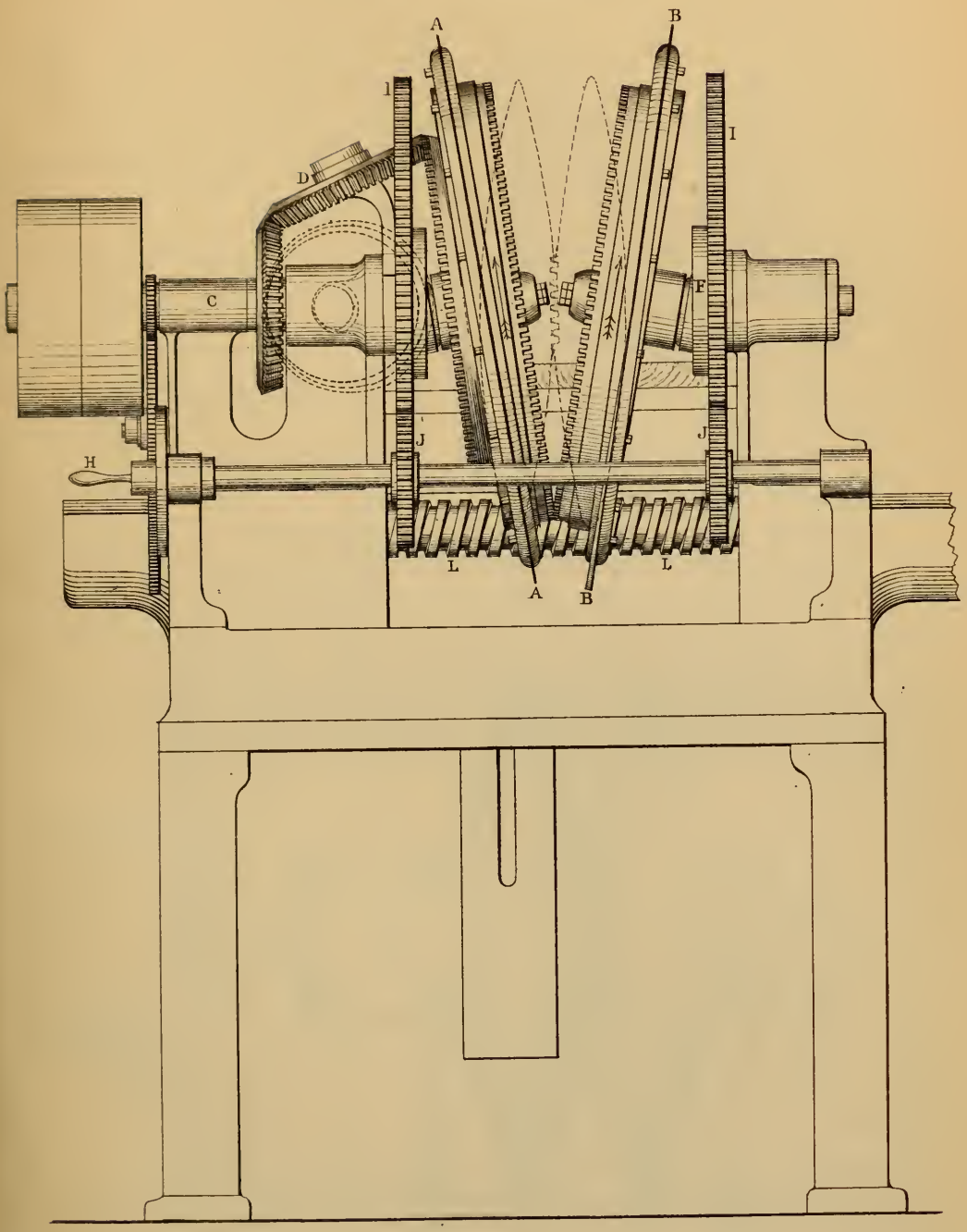
Fig. 1. *Side Elevation.*



(Proceedings Inst. M. E. 1868.)

Scale 1/40th.

Fig. 2. *Back Elevation.*

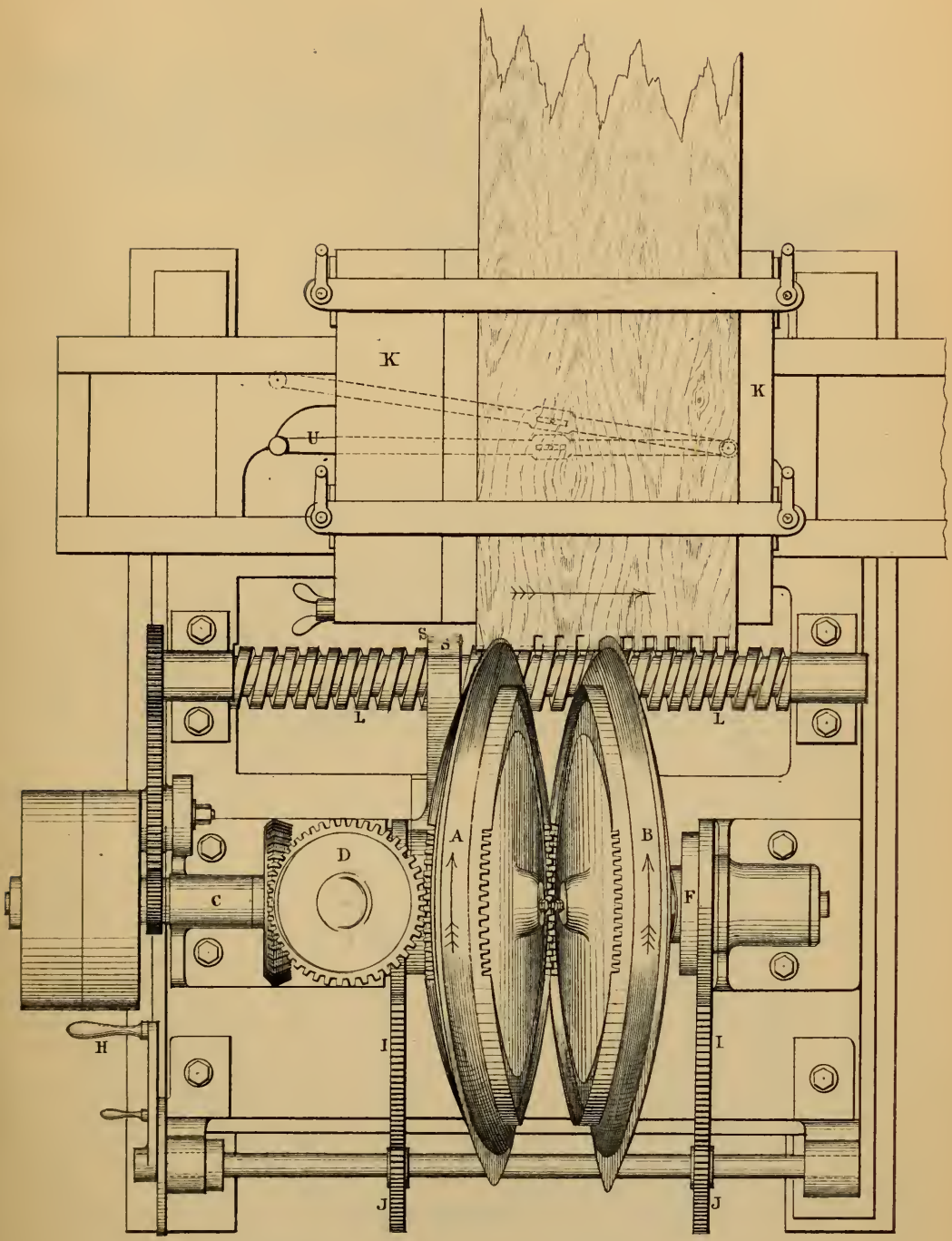


(Proceedings Inst. M E. 1868)

Scale 1/10th

0 5 10 15 20 25 30 Inches

Fig. 3. *Plan.*



(Proceedings Inst. M.E. 1868.)

Scale 1/10th.

0 5 10 15 20 25 30 Inches.

DOVETAILING MACHINE.

Detail of Circular Saws

Plate 24.

Fig. 4. *Side Elevation.*

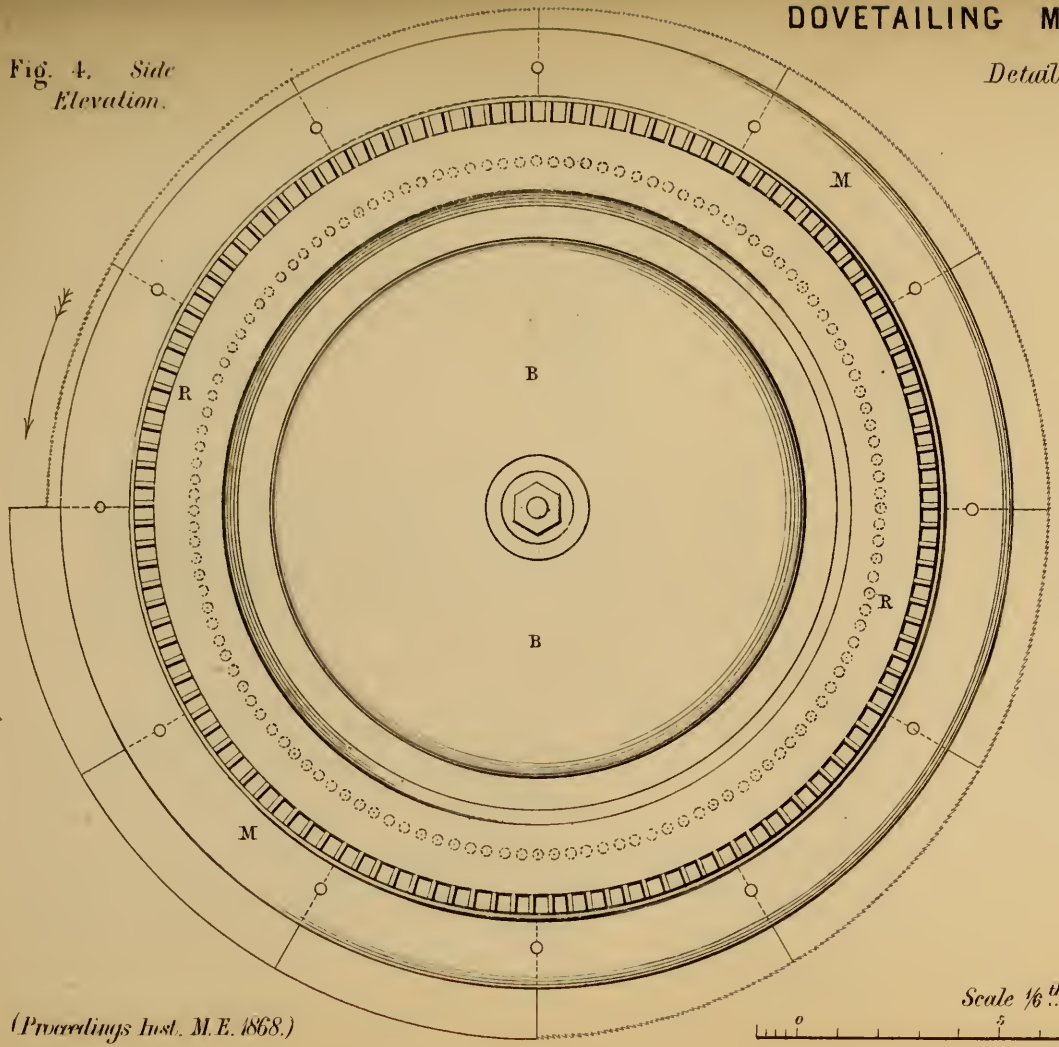
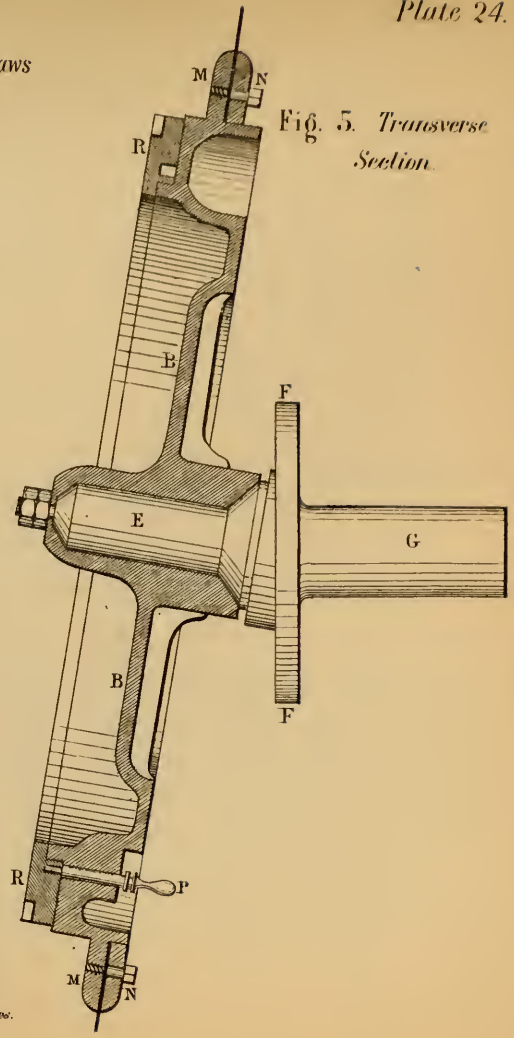


Fig. 5. *Transverse Section.*



Scale 1/6th.

0 5 10 Inches.

(Proceedings Inst. M.E. 1868.)

DOVETAILING MACHINE.

Plate 25.

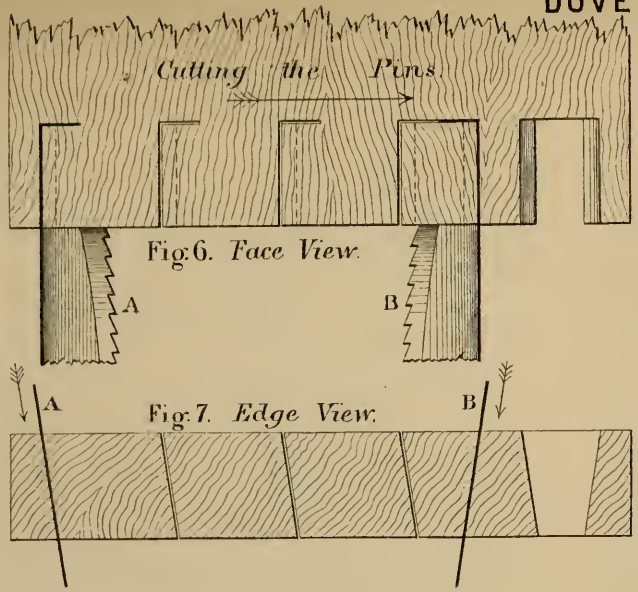


Fig: 6. *Face View.*

Fig: 7. *Edge View.*

Ordinary dovetails.

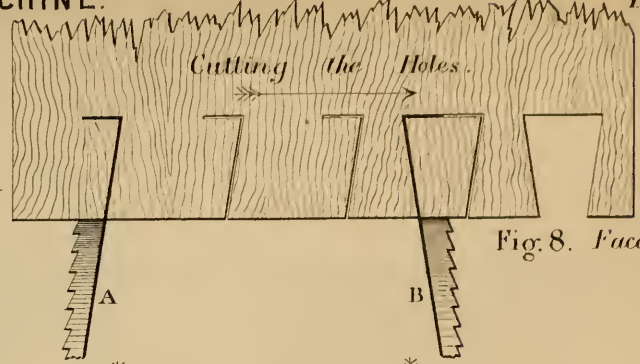


Fig: 8. *Face View.*

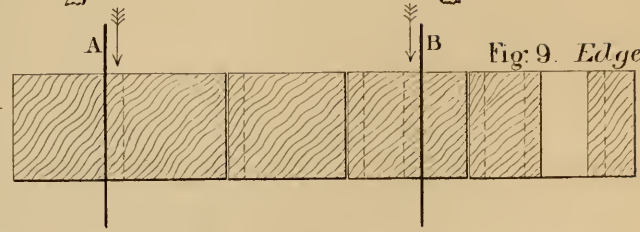


Fig: 9. *Edge View.*

Concealed dovetails for mitre joints.

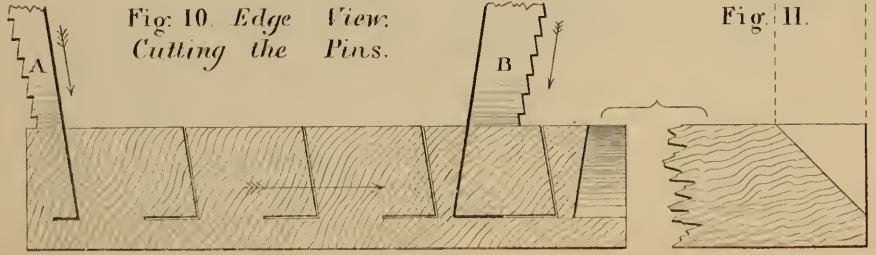


Fig: 10. *Edge View. Cutting the Pins.*

Fig: 11.

Fig: 12.

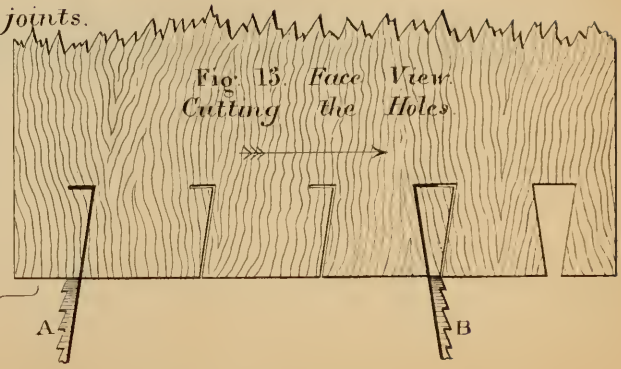


Fig: 13. *Face View. Cutting the Holes.*

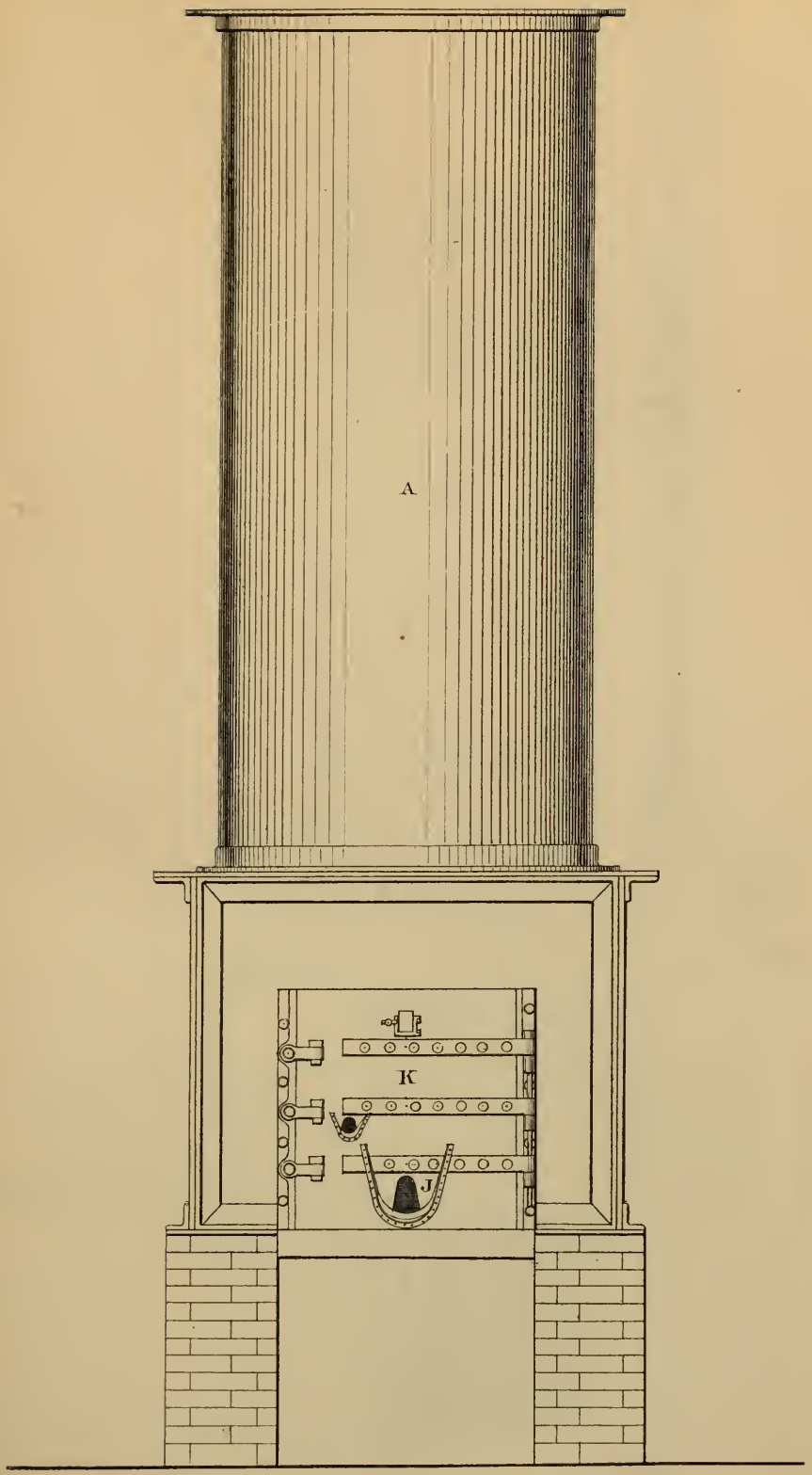
(Proceedings Inst M. E. 1868.)

Scale half full size.

FOUNDRY CUPOLA.

Plate 26.

Fig. 1. *Front Elevation.*



(Proceedings Inst. M.E. 1868.)

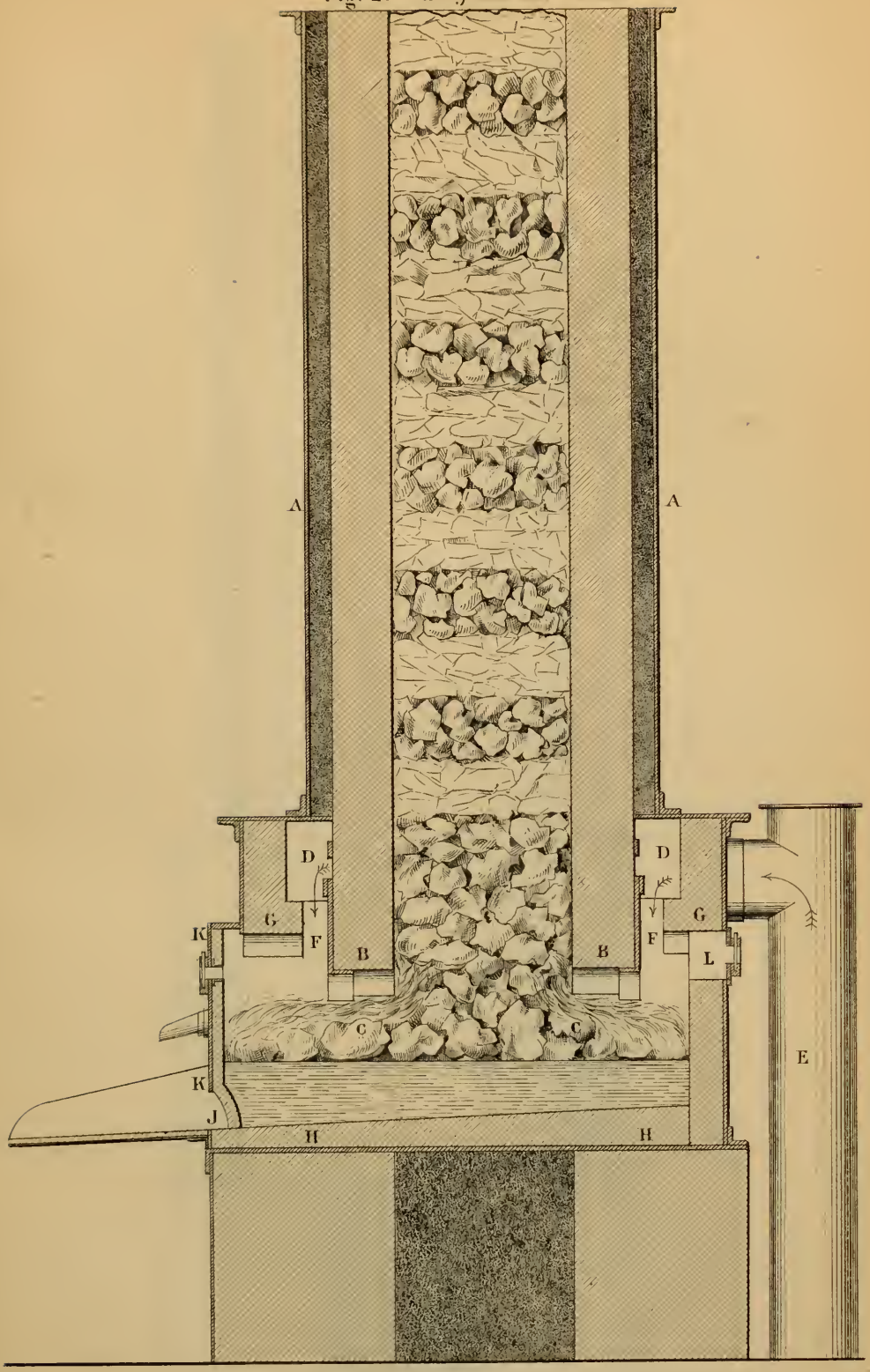
Scale $\frac{1}{20}^{th}$

10 5 0 10 20 30 40 50 60 70 80 90 100 *Inches.*

FOUNDRY CUPOLA.

Plate 27.

Fig. 2. *Longitudinal Section.*



(Proceedings Inst. M.E. 1868.)

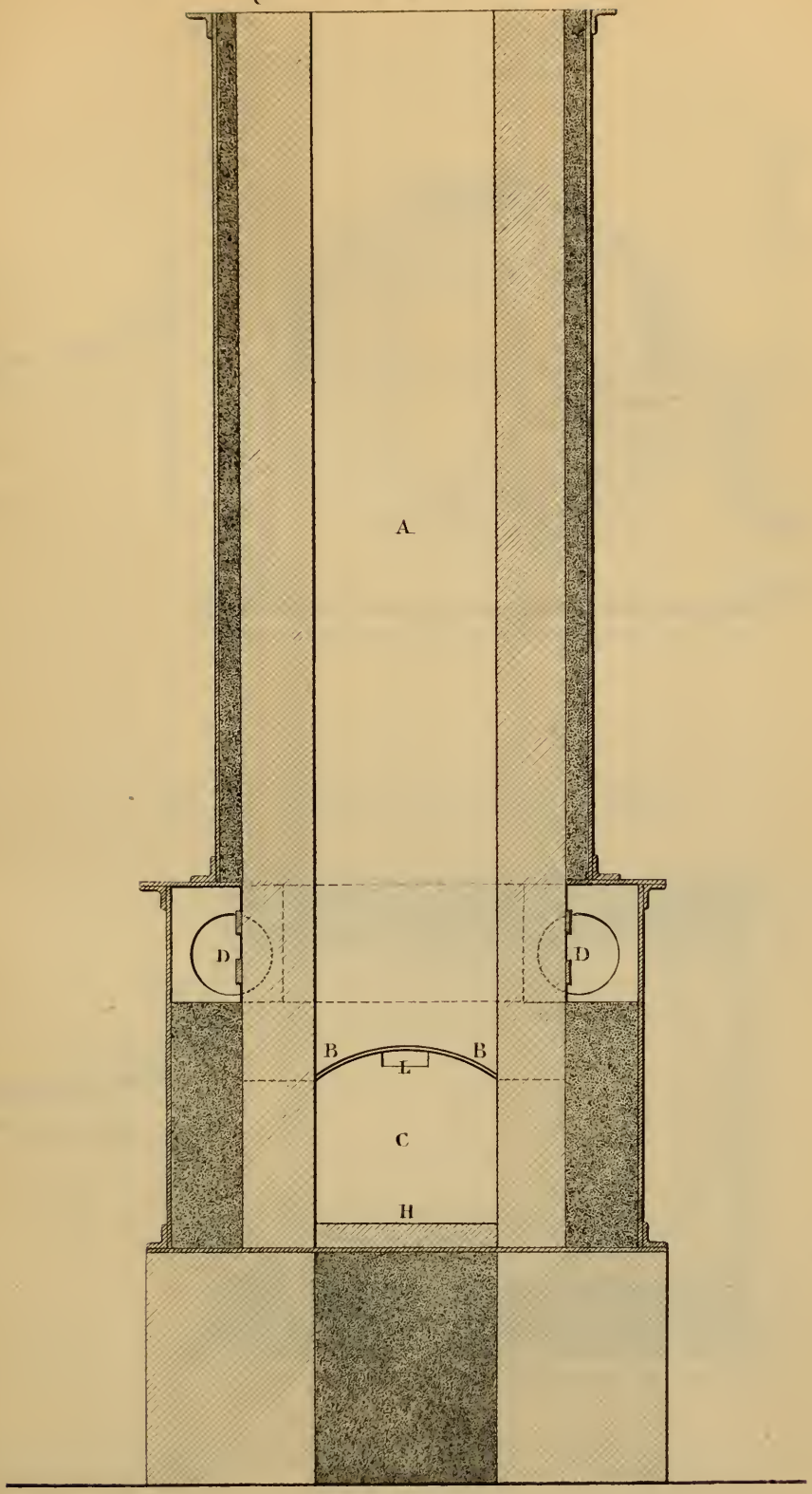
Scale $\frac{1}{30}^{th}$

10 5 0 10 20 30 40 50 60 70 80 90 100 Inches.

FOUNDRY CUPOLA.

Plate 28.

Fig. 3. *Transverse Section.*



(Proceedings Inst. M.E. 1868.)

Scale 1/30 th

80 5 0 40 20 30 40 50 60 70 80 90 100 Inches.

Fig. 4. *Sectional Plan through shaft and through Air Chambers.*

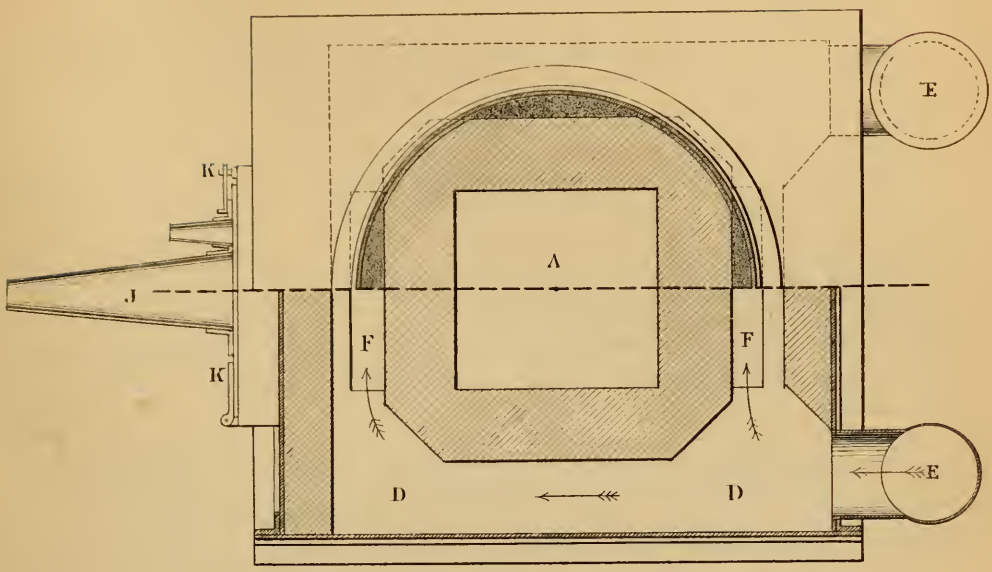
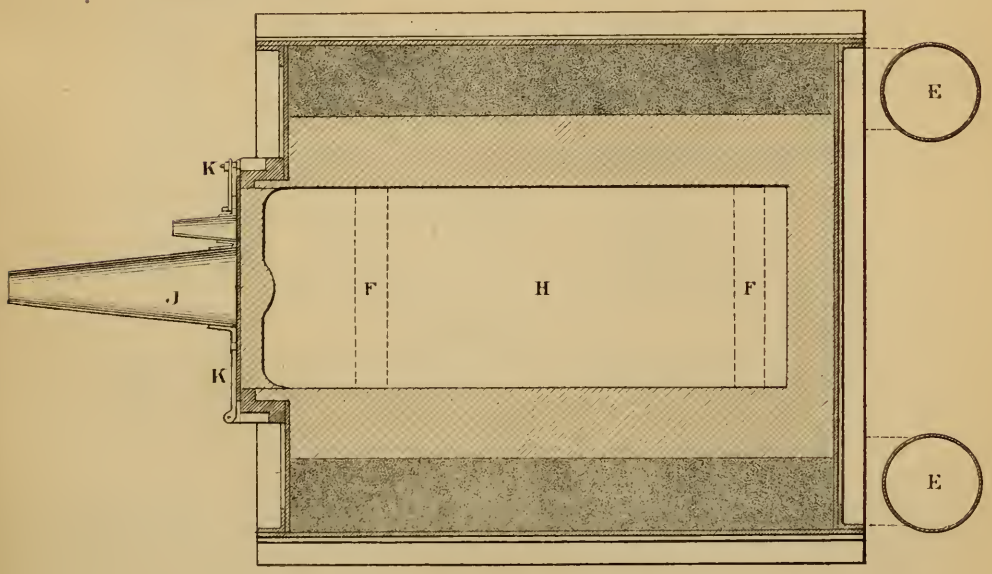


Fig. 5. *Sectional Plan at level of Hearth.*



(Proceedings Inst. M.E. 1868) *Scale $\frac{1}{30}^{th}$*

40 5 0 10 20 30 40 50 60 70 80 90 100 Inches.

PROCEEDINGS.

30 April, 1868.

The General Meeting of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Thursday, 30th April, 1868; Thomas Hawksley, Esq., Vice-President, in the Chair.

The Minutes of the last Meeting were read and confirmed.

The Chairman announced that the Ballot Lists had been duly opened, and the following New Members had been found to be elected :—

MEMBERS.

Thomas Carrington, Jun.,	Sheffield.
Henry Wheeler Davis,	London.
Enoch Horton,	Darlaston.
Robert Jobson,	Dudley.
William Gregory Norris,	Coalbrookdale.
Henry Parker,	Kurrachee, India.
William Rogers,	Adelaide, Australia.
George Robert Stephenson,	London.
Frederick Bevoley Vallance,	Greenwich.
Peter Ormerod Whitehead,	Manchester.

GRADUATE.

William Henry Dugard,	Birmingham.

The Chairman announced that the following communication had been received from the Patent Office, requesting the Institution to nominate gentlemen for the appointment to be made by Government of one out of three additional Commissioners of Patents :—

Patent Office, 28th April, 1868.

Dear Sir,

I have been directed by the Lord Chancellor and the Master of the Rolls to transmit to you copies of a Memorial presented to the Master of the Rolls on the 20th ult., and his Lordship's reply to Mr. Dillwyn dated 31st March; and to request that you will submit them to the Members of the Institution of Mechanical Engineers, in order that they may be pleased to nominate gentlemen with the requisite qualifications for the proposed appointments.

Yours truly,

B. WOODCROFT,
Clerk to the Commissioners of Patents.

The Secretary,
Institution of Mechanical Engineers.

(*Copy of the Memorial.*)

TO THE RIGHT HONOURABLE THE LORD ROMILLY,
MASTER OF THE ROLLS.

My Lord,

The great use of Patents is to make known the inventions, processes, and secrets of others. It is therefore highly important that the mass of information accumulated at the Patent Office should be made available, so as to make known as far as possible all inventions and modes of manufacture for the benefit of the country. The advantage of so doing would be immense, and would help to keep the manufactures of this country in advance of others. Action in this direction on the part of the authorities has been prayed for in every memorial that has been presented.

One of the first Memorials was presented by the Institution of Mechanical Engineers, with Mr. Robert Stephenson as President at its head. This was presented in 1853 to the Right Honourable Frederick Lord Chelmsford, Lord High Chancellor of Great Britain, the Right Honourable Sir John Romilly, Master of the Rolls, Sir

Fitzroy Kelly, Her Majesty's Attorney General, and Sir Hugh McCalmont Cairns, Her Majesty's Solicitor General; and prayed for greater facilities being given to persons making enquiries in any branch of knowledge at the Patent Office.

The second Memorial in 1862 was presented to the Right Honourable Sir John Romilly. It prayed amongst other things for "a building as an Office for Patents, including in it a complete library, a commodious reading room, and suitable offices for a proper staff of clerks and others to prepare well-digested and numerous abstracts and abridgments of inventions and processes, made public either by the specifications of patents or otherwise, and whether English or Foreign."

A third Memorial was presented to Sir John Romilly in 1864. It prayed not only that the efficiency of the office should be increased, but called the attention of the Commissioners to recent reductions in the staff and its disorganised state; which staff was "utterly inadequate to satisfy the requirements of persons seeking information among the very numerous works contained there." The memorialists went on to state that "they had entertained the hope that, so far from a reduction being made, there would have been an increase ordered to such an extent as would have enabled the abridgments of the specifications in the various branches of art (which abridgments were commenced about seven years ago) to be pushed vigorously forward, so as to complete the abstracting of the whole of the original specifications, and to keep up those abstracts from year to year as new matter is furnished. Your memorialists feel it is hardly possible to overrate the advantages to be derived by the public from a complete and intelligent system of abstracts; and they venture to urge upon the consideration of the Commissioners the necessity of at once providing a sufficient number of qualified persons (to be under the entire control of the scientific officer appointed by the Commissioners to superintend the specifications) to assist that officer in preparing such abstracts, and also to collect and epitomise scientific information generally."

The President and Members of the Institution of Mechanical Engineers addressed a Memorial in 1864 to the Right Honourable

Lord Westbury, then Lord Chancellor, bringing under his Lordship's notice the fact "that very great loss and delay are occasioned to manufacturers, inventors, and others, by the want of a complete classification and the prompt Indexing of all inventions, whether patented or not, Foreign as well as English. Such a systematic arrangement as is needed is quite within the compass of an efficient staff of officers possessed of technical knowledge, and could be at once proceeded with; the state of inventions could then be ascertained, and the common case of several persons patenting the same thing would be avoided."

In 1864 a Select Committee of the House of Commons enquired at great length into the working of the Patent Office; and reported, in accordance with the general tenor of the evidence, that much more was required to be done at the Patent Office to render it efficient; that more attendants were required, and "that the want of increased accommodation was so much felt as to prejudice the due administration of the Patent Law" (paragraphs 3 and 4 of Report; answers 10 to 13, 18 to 21, 658 to 662, 667, 817, 863, 1038, and 1039 of Evidence).

We merely allude to the opinions expressed by the Select Committee of the House of Commons, scientific men, manufacturers, engineers, and inventors, as the various memorials and other documents are in the possession of the Commissioners of Patents; but we would further mention that the various Commissioners of Patents have from the year 1858 reported from time to time to the Lords of the Treasury that great improvements were wanted and a good building urgently required for the purposes of the Patent Office.

In conclusion we beg to state that it is our decided opinion, and that of many of those who have signed various memorials, that it would conduce greatly to the progress of manufactures and the advancement of commerce, if the large stock of knowledge of inventions and processes, both patented and open, stored at the Patent Office, were made available to manufacturers and the public generally; and this your petitioners believe would best be compassed, if Her Majesty were graciously pleased to appoint that "other person

as Commissioner of Patents," as contemplated by the Patent Law Amendment Act of 1852, and if the staff at the Patent Office were augmented by the addition of a sufficient number of persons, possessed of good technical knowledge and well able to abstract all specifications as they came in daily, so that they might at once be entered into an efficient Subject-Matter Index, which would give a true indication of what was in the specifications. In addition to this of course the large number of specifications already at the office would require to be abstracted and entered in a similar manner in a new edition of subject-matter indexes, that would really indicate what was contained in each specification, which the present indexes do not. Further we beg to urge that similar subject-matter indexes be formed of all inventions and processes comprised in the very numerous indexes and tables of contents of the scientific books contained in the excellent scientific and technical library of the Patent Office; so that any person using due diligence might easily learn with tolerable certainty whether an invention were new or old, which is not now the case.

We beg to append a sample page of such two subject-matter indexes as we would submit are urgently required. It is almost superfluous to mention that there are now several hundred thousands of pounds accumulated surplus, and an annual surplus of about sixty thousand pounds, contributed by the very class of persons who would benefit by such improved indexes.

L. L. Dillwyn, M.P.
Richard Baggallay, M.P.
Charles Fox, Mem. Inst. C.E.
Charles Hutton Gregory, President Inst. C.E.
Edward Woods, Mem. Inst. C.E.
C. William Siemens, Mem. Inst. C.E., F.R.S.
Robert Mallet, Mem. Inst. C.E., F.R.S.
Frederick J. Bramwell, Mem. Inst. C.E. Council.
Edward A. Cowper, Mem. Inst. C.E.

20th March, 1868.

(*Copy of Reply of the Master of the Rolls to Mr. Dillwyn.*)

Rolls, 31st March, 1868.

Sir,

I transmitted to the Lord Chancellor the Memorial presented to me on the 20th March instant by yourself and the gentlemen who accompanied you, relative to the present state of the Patent Office, together with my views on the subject; and we have since considered the matter in consultation together.

The result of this is that we are prepared to recommend to Her Majesty's Government that three gentlemen should be appointed to act as Commissioners of Patents together with the Lord Chancellor and the Master of the Rolls for the time being: one to represent Mechanical Science, another to represent Chemical Science, and a third to represent the subjects more usually and more especially comprised in the term Natural Philosophy. We should propose that the gentlemen to be recommended to Her Majesty for this purpose should be, as regards the first, from gentlemen to be nominated by the Society of Mechanical Engineers; as regards the second, from gentlemen to be nominated by the Chemical Society; and as regards the third, from gentlemen to be nominated by the Council of the Royal Society. But we are not prepared to recommend that any salary should be attached to the services of these gentlemen. We trust and believe that gentlemen fully competent for the purpose may be found, who have sufficient leisure, and who, from their love of science and their desire to disseminate more widely the discoveries made in these branches of science, would be willing to give their services without remuneration, and to superintend the general management of the Patent Office, to see that the Indexes and Abstracts of the Specifications are made accurate and complete, and to redress the other defects complained of in your memorial: acting in all these respects in conjunction with the Lord Chancellor and the Master of the Rolls, to whom they would refer whenever the occasion might require it.

I think it however desirable to repeat that, on fully considering the subject, both the Lord Chancellor and myself have arrived at the conclusion that it would be inexpedient to create either one or more salaried officers for this purpose; and to say that we should both, if applied to, recommend Her Majesty's Government not to accede to that part of the views of the gentlemen who composed the deputation, which had relation to the creation of paid officers.

ROMILLY.

L. L. Dillwyn, Esq., M.P.

The following gentlemen were accordingly nominated by the Meeting for the above purpose :—

Mr. Charles Edwards Amos, ... London.
Mr. Robert Charles May, ... London.

The following paper was then read :—

ON THE ALLEN ENGINE AND GOVERNOR.

By Mr. CHARLES T. PORTER, of Manchester.

The objects to be aimed at in carrying out expansion in a steam engine, so as to effect the greatest economy, may be stated to be:—that the full boiler-pressure should be carried into the cylinder at the commencement of the stroke, and maintained up to the point of cut-off;—that the cut-off should be sharp, without reduction of the steam pressure by wire-drawing;—and that the exhaust should be invariable, allowing the steam pressure to act to the end of the stroke with all degrees of expansion, and discharging the steam with the least loss from back pressure during the return stroke.

The attainment of these objects has generally been considered practicable only by means of some kind of liberating valve-gear, in which the valve is released from the gear when wide open, and is closed suddenly by a spring or by the action of gravity; so as to avoid the reduction of pressure by wire-drawing, which ordinarily takes place through the gradual closing of the steam port by a slide-valve worked with a continuous motion. Many ingenious constructions of liberating valve-gear have been invented for effecting this object, more particularly in America, where the subject has received great attention; and amongst them may be specially mentioned the Corliss engine now introduced into this country, which has been found to accomplish the desired end very successfully.

In the Allen Engine however, forming the subject of the present paper, the preceding requirements are met by a direct continuous action of the slide-valves; which gives a sharp cut-off to the steam admitted at full boiler-pressure, and a high range of expansion, together with a very free exhaust. At the same time this arrangement obviates the objection attending the principle of a liberating

valve-gear, namely that the speed at which the engine can be worked is limited by the circumstance of the valve having to be disconnected from the driving gear and connected again at each stroke of the engine. The Allen engine admits of being worked at a very high speed, much higher than is usual in stationary engines; and it maintains complete steadiness of motion at this high speed, combined with a great uniformity in the driving power throughout each revolution, although the steam is admitted at an unusually high pressure at the commencement of the stroke.

The engine is represented in Figs. 1 and 2, Plate 9, which show a side elevation and plan of an engine with cylinder of 12 inches diameter and 24 inches stroke. This engine has been running some months at the works of the Whitworth Co., Manchester, at a constant speed of 200 revolutions per minute or 800 feet per minute speed of piston, driving a considerable portion of the machinery in the works; and a similar engine was worked at the late Paris Exhibition, running at the same speed. The engine is horizontal, fixed upon a bed-plate, and working an air-pump direct from the piston-rod, which is prolonged through the outer end of the cylinder. The slide-valves are worked by a link motion, which is controlled entirely by the governor, giving a variable degree of expansion according to the amount of work to be done by the engine; but the steam is always admitted to the cylinder at full boiler-pressure, without passing through a throttle-valve.

Valves and Valve Motion.—The steam slide-valves are shown in the longitudinal and transverse sections of the cylinder, Figs. 3 and 4, Plates 10 and 11. The steam valves are independent of the exhaust valves, and two separate valves are employed, one for each port. The two steam valves E E are driven with separate motions, independent of each other, so as to effect a sharp cut-off at each end of the cylinder by the rapid motion of each valve at the point of closing the port; the motion of one valve being rapidly accelerated at the point of cut-off, at the same time that the other valve is greatly retarded. Each steam valve consists merely of an open rectangular frame sliding between two parallel faces, which are fixed, so that the valve is in

equilibrium and its motion is not affected by the pressure of the steam. The outer face F, against which the back of the valve slides, is a rigid plate bridging across the port and fixed down solid to the port face; and it is adjusted so as to allow the valve to slide freely, but with so good a fit as to be steam-tight. The travel of the valve in opening extends beyond the two faces, so as to admit the steam to the port at four places simultaneously, as shown in the separate diagrams, Figs. 13 and 14, Plate 15, in which the length of the valve-rods and the distance between the valves are shortened for convenience in the diagram. In Fig. 13 the steam is shut off from the nearer port; and in Fig. 14 the further steam valve is shown at the point of opening the port, just previous to the commencement of the stroke, the crank being at that moment in the position shown by the dotted line.

In order to maintain the proper working of these valves, the back plate F, Figs. 3 and 4, is made very rigid, so as to prevent any yielding under the pressure of the steam; and the entire plate with its side supports being surrounded by the steam is consequently exposed to the same expansion as the slide-valves. In order to provide the means of adjustment in case of any wear, a packing strip is inserted on each side between the back plate and its side supports; so that by reducing the thickness of these packing strips the two faces can be readily let together at any time to fit the slide-valve. The wear is found however to be so exceedingly slight, on account of the absence of pressure on the rubbing surfaces, that there is no probability of any adjustment being required oftener than once a year.

The exhaust valves G G are also two separate valves, as shown in Figs. 3 and 4, and in the diagram, Fig. 15; but they move together and are driven by the same valve-rod. These slide-valves are of the ordinary form, and work in separate chambers, between the steam valves and the cylinder; they travel beyond the port face, so as to open for the exhaust at the two edges simultaneously. As the steam valves however open at four places simultaneously, the exhaust valves are made of nearly double the width, as shown in Figs. 4 and 6, in order to give a corresponding area of opening; and

the extent of their motion is such as to give an area of opening for release of the steam more than double the largest area for admission. These valves work in equilibrium through most of their stroke.

Although there are thus four separate valves for the steam and exhaust, the motion of all of them is obtained from a single eccentric, which is fixed on the crank shaft in the same position as the crank and without any lead, as shown in the diagram, Fig. 16, Plate 16. The eccentric is shown in Figs. 10 to 12, Plate 14, and has a curved slot in one side of the strap, which acts as the expansion link; and it is guided in its motion by being connected to the upper end of the vibrating lever H centred below. Two valve-rods, I and J, are connected to the same slide-block in the link, and attached at the other end to two separate bell-crank levers upon intermediate rocking shafts, as shown in the diagrams, Figs. 13 and 14. One of these rocking shafts is made tubular, with the second running through it, as shown at K in Figs. 11 and 12, so that the two shafts work independently of each other. The second arms of the two bell-crank levers are connected respectively to the two steam valves, Figs. 13 and 14. The slide-block in the expansion link is carried by two side links from the arm of the governor, as shown in Fig. 1, so that its position is regulated entirely by the governor, the block being lowered so as to cut off the steam earlier whenever the governor balls begin to fly out in consequence of any increase of velocity.

The motion of the exhaust valves is invariable, and they are connected direct to a point L, Figs. 10 and 12, beyond the outer end of the link slot. A greater travel is thereby given to the exhaust valves, as shown in Fig. 15, than the greatest travel of the steam valves; and this motion is continued the same during every change of expansion produced by shifting the slide-block from which the steam valves are moved, so that the exhaust continues equally free with every degree of expansion. The point of connection to the link is so placed as to give the required lead to the exhaust valves, and is arranged beforehand to suit the intended speed of piston. The exhaust valves are driven through an intermediate rocking shaft M, Fig. 12, for reversing the motion obtained from the eccentric; and a pair of valve spindles are used, one at each edge of the two valves, as

shown in Figs. 4 and 6, and working within the intermediate exhaust port, Fig. 3. The spindles are guided at each end, and each valve is connected to them by two studs fixed in the valve, which fit into slots in the spindles, working clear within the opening of the ports, Figs. 3, 4, and 15. In the case of the steam valves, as the two valves have independent motions, the spindle for driving the further valve passes free through a short tube in the lower side of the nearer valve, Fig. 4; the two spindles are made to clear each other by the valves being placed out of line with each other, as shown in the elevation of the steam port faces, Fig. 5; the spindles are kept central in each of the valves.

All the valves are readily accessible by simply removing the nuts of the steam-chest cover N, Figs. 3 and 4, as the steam-chest is not cast solid upon the cylinder, but is a separate rectangular frame O O, fitted down with a scraped joint on both faces, and secured by the same through-bolts that fix the cover N. This construction has the important practical advantage that the steam-chest can be entirely removed, and all the port faces can be readily got at like plain outside surfaces.

In this valve motion the proportion between the throw of the eccentric and the length of eccentric-rod, or the distance from the centre of the eccentric to the centre of the link, is made the same as the proportion between the main crank and the connecting-rod, which in this engine is 1 to 6, or the length of connecting-rod is 3 times the stroke. Consequently as the eccentric is set exactly to correspond in position with the crank, the angular vibration of the one compensates for that of the other, and an exactly correct valve-motion is obtained, giving the same results for each end of the cylinder. A considerable difference often exists in the indicator figures taken from the opposite ends of a cylinder, in consequence of the discrepancy between the motions of the connecting-rod and the eccentric-rod; and the difference in speed of piston during the first 1° of rotation of the crank at the extreme opposite ends of the stroke amounts to 28 per cent. of the higher speed when the connecting-rod is 6 times the crank, 33 per cent. when 5 times, and 40 per cent. when 4 times the crank.

In such cases therefore the point of cut-off is not the same in the two strokes of the piston; but in the present engine the two strokes are identical throughout, in consequence of the eccentric and connecting-rods having exactly parallel and simultaneous motions.

The connection of the expansion-link to the steam valves by the intermediate bell-crank levers introduces in effect a toggle-joint movement, which has the important advantage of allowing the length of the valves to be reduced very considerably, because more than half of the lap or useless motion of the valves after having covered the ports is dispensed with by their motion being greatly retarded at that time; whilst the opening for steam admission is correspondingly increased by the motion of the valves being accelerated at the opposite extremity of their travel. This variation in the motion is shown by the diagram of the link motion in Fig. 16, and also in Figs. 13 and 14, together with the varying angular motion of the bell-crank levers on the rocking shaft, the reference letters indicating corresponding positions throughout. The result is seen to be a very great range of variation in the motion of the valves, giving on the one hand a wider steam opening and a sharp cut-off with high degrees of expansion, and on the other hand a very slow motion of the valve during the time that it is simply retaining the port closed. The whole action is obtained with a continuous and perfectly smooth motion throughout.

In the adjustment of the centres of the link motion, the centre of the supporting lever H, Fig. 12, is slightly lowered, so that its upper end vibrates entirely below the centre line, as shown in Fig. 16, in order thereby to equalise the extent of tipping of the link at the two extremities of its vibration. This gives a slightly increased lead to the steam-valve opening at the further end of the cylinder, where the motion of the piston is the more rapid on account of the smaller arc of rotation of the crank; but the point of cut-off of the valves is exactly the same at the opposite ends of the cylinder for each degree of expansion, and the point of cut-off can be varied from 4-10ths of the stroke to the very commencement of the stroke.

Indicator diagrams are shown in Fig. 18, Plate 18, taken from this engine, at the speed of 200 revolutions per minute or 800 feet

per minute speed of piston; and those in Figs. 19 and 20, Plates 19 and 20, are taken from two larger engines with 18 and 20 inch cylinders working at the speed of 600 feet per minute. This speed of 600 feet per minute is the one that has been adopted in practice for these engines; but the continued successful working of those running at 800 feet per minute shows the higher speed to be quite practicable. The indicator diagrams in Fig. 19 are taken from an engine at Messrs. Pooley's Cotton Mill, Manchester, having a cylinder 18 by 30 inches, and working at 120 revolutions per minute; those in Fig. 20 are from an engine at Messrs. Evan Leigh's works, Manchester, with 20 by 36 inch cylinder, and working at 100 revolutions per minute. In Fig. 19 are shown the effects of wet steam in destroying the sharpness of cut-off, as the boiler was sending over a great deal of water with the steam; and in Fig. 20 a sharp cut-off is shown, as the engine was working with dry steam. The vacuum shown in Fig. 20 is deficient, because the condenser was not in good order. In Fig. 19 the lower straight dotted line A shows the vacuum in the condenser, and the upper straight dotted line B the vacuum in the exhaust chamber at the time of taking the dotted indicator diagram.

The valve motion shown in the drawings is arranged for an engine running always in one direction, as in the case of driving shop machinery; but when a reversing action is required, the expansion-link slot is simply prolonged to an equal distance below the centre line, and exactly similar actions are then obtained in the opposite direction, in consequence of the position of the eccentric being exactly in correspondence with that of the crank.

For the purpose of obtaining the full benefit of expansion, it is requisite, in addition to having the full boiler-pressure in the cylinder and providing a sharp cut-off, that superheated steam should be used, in order not only to prevent water from being carried over into the cylinder with the steam, but also to prevent any loss arising from the freshly admitted steam becoming condensed in the cylinder by contact with the cylinder surface which has been cooled in the previous expansion. About 50° Fahr. of superheating is found desirable; and this proves a more efficient mode than steam-

jacketting, because the superheated steam on admission into the cylinder supplies heat to the very surfaces that have been cooled by exposure to the low-pressure expanded steam.

Speed of Piston.—One of the objects aimed at in this engine is to work at speeds considerably higher than those ordinarily used in any but locomotive engines. For the following reasons it is considered that the speed of piston should not be less than 600 feet per minute; but these engines have been worked continuously at the higher speed of 800 feet per minute with complete success, and it is believed that still higher speeds may in some cases be employed with advantage. The valves and the whole of the working parts are so well adapted to maintain a high speed, that the practical objections which ordinarily limit the speed of piston to lower rates do not apply in the case of the present engine.

The principal object in adopting the high speed of piston is to obtain a sufficient reciprocating force in the moving parts for balancing the initial force of the steam upon the piston when admitted at full boiler-pressure at the commencement of the stroke, so as to relieve the crank from strain on passing the centres; and also to equalise more fully the driving force upon the crank during the entire stroke. At the commencement of each stroke, an accelerating force is required sufficient to put in motion the mass of the reciprocating parts at the velocity at which the piston moves from a state of rest; and the speed of piston is adjusted so as to make this required force as great as the actual full force of the steam upon the piston when admitted at the boiler pressure, so that the two forces are in equilibrium at that point and the crank pin is thereby relieved from strain when passing the centre. This accelerating force imparted to the piston at the commencement of the stroke is given out again during the retardation of the piston in the latter half of the stroke, and thus compensates for the diminishing driving force of the expanding steam, and acts to equalise the driving power upon the crank. A similar action takes place in all engines, but at the speeds of piston ordinarily employed its extent is too small to produce any material effect; and it is only with a high speed that the effect becomes

important, since the force required to put in motion or to stop the reciprocating parts increases as the square of their velocity of motion. Where a high speed is combined, as in this engine, with an unusual weight of the reciprocating parts and a short stroke, the inertia of these parts acts as a powerful reciprocating flywheel to equalise the driving power of the engine throughout the revolution of the crank.

In the present engine the weight of the reciprocating parts is 470 lbs., the cylinder 12 inches diameter by 24 inches stroke, and the number of revolutions 200 per minute, or one revolution in 0·3 second. Taking the motion of the piston in the first 1° of revolution of the crank at the commencement of the stroke, the extent of motion will be the versed-sine of an angle of 1° with a radius of 1 foot, or 0·000152 foot in the time of $\frac{1}{360}$ of 0·3 second, or $\frac{1}{1200}$ second; which is equivalent, as regards the accelerating force required to produce it, to a motion of 219 feet in one second, the space passed through under a uniform accelerating force being in proportion to the square of the time. This motion of 219 feet in one second is 13·7 times the effect of gravity (16·08 feet in one second); and consequently the force required to impart the velocity amounts to 13·7 times the weight of the reciprocating parts (470 lbs.), making a total force of 6439 lbs., which is equal to a pressure of 57 lbs. per square inch upon the area of the 12 inch piston. It follows therefore that the steam at the full pressure of 57 lbs. may be admitted suddenly to the cylinder at the commencement of the stroke, without causing any strain upon the crank pin; and indeed this full pressure is absolutely required upon the piston at that moment, in order to prevent a strain in the opposite direction upon the crank pin from the inertia of the reciprocating parts.

This principle is carried out in the regular working of the engine shown in the drawings, which has been running constantly for some months at the Whitworth Co.'s works with the speed of piston of 800 feet per minute; it is worked in direct communication with a boiler of 60 lbs. pressure, without any intermediate throttle-valve to reduce the pressure of the steam before entering the cylinder. The indicator figures given in Figs. 18, 19, and 20, show an excessive variation of pressure upon the piston throughout the stroke, ranging

from 70 lbs. down to 10 lbs. per inch total pressure above a perfect vacuum; but in order to ascertain the effective driving power upon the crank, the whole amount of the pressure due to the inertia of the reciprocating parts has to be deducted at the beginning of the stroke, and the same amount has to be added to the indicator figure at the end of the stroke, both amounts being gradually reduced to nothing at the middle of the stroke. This correction acts directly to compensate for the inequality of the indicator figure, and the effective driving power throughout the stroke is thereby equalised to a remarkable extent. In the diagram, Fig. 17, Plate 17, the pressure produced upon the crank pin by the inertia of the reciprocating parts during the acceleration and retardation of the piston in each half of the stroke is represented by the dotted line A A, the amount of the pressure at the beginning of the stroke being represented by the distance A C from the horizontal base line C C; this diminishes to nothing at the middle of the stroke, and becomes an equal amount of pressure A C at the end of the stroke, but in the opposite direction. The rate of change is uniform, during equal spaces passed through by the piston, and is represented by the straight dotted line A A, if the varying angular motion of the connecting-rod be neglected; but when this is taken into account, the result is modified practically to the slightly curved line B B.

For carrying out a high degree of expansion a high speed of piston is essentially requisite, in order that a sufficient amount of equalising effect may be obtained from the inertia of the reciprocating parts, to compensate for the extreme variation in steam pressure which is consequent upon an early cut-off. Indeed in consideration of smoothness of running, the engine should be run so fast that the driving force produced by the highest pressure of steam cannot exceed the inertia of the reciprocating parts; and then a knock upon the centres becomes as impossible as it would be in a revolving sling.

A high speed of piston is also advantageous on account of the reduction in size of engine required to supply a given amount of

power, whereby an important saving in space and cost is effected; and also on account of the increased uniformity of motion obtained with the higher speed. Taking the case of a single engine in place of a pair of coupled engines running at half the speed, the strokes are as frequent as those of the pair of engines, while the inequalities in the rotative force are not much larger, owing to the great equalising effects of the inertia of the reciprocating parts at the high speed. Moreover as the regulating power of the flywheel increases in proportion to the square of the number of revolutions in a given time, the same wheel has four times the regulating power when run at double the speed.

The practical objections generally considered to apply to a high speed of working are, increased wear and tear, risk of hot bearings, cutting of the cylinders and pistons, and shaking loose in the fixings. But instead of any difficulties of this kind having been experienced, this engine runs smoothly and quietly, without tremor and without warming in the bearings, running continuously without requiring attention, and showing exceedingly slight wear in the cylinders, valves, and bearings. This result has been attained simply by good mechanical construction and workmanship; avoiding any unbalanced action, overhanging strains, insufficient stiffness of framing, inadequate bearing surface, or want of truth in workmanship. Unless all these conditions are carefully attended to, high speed is certainly not practicable; but when they are thoroughly carried out, no difficulty is experienced in working at any desired speed.

In the previous consideration of the effect produced by the inertia of the reciprocating parts, this has been taken as the same at each end of the stroke; but in reality a considerable difference is caused by the angular motion of the connecting-rod at the two ends of the stroke; and the actual motion of the piston during the first 1° of rotation of the crank, instead of being 0·000152 foot at each end, is 0·000178 at the outer end of the stroke, and only 0·000127 at the inner end. Consequently, from this approximate mode of calculating by the difference in motion of the piston during the first degree of rotation from each end of the stroke, the pressure on the piston required to balance the inertia, instead of being 57 lbs. per inch at

both ends as named before, would be 66 lbs. at the outer end and $47\frac{1}{2}$ lbs. at the inner end. In the case of inverted vertical engines, the weight of the reciprocating parts acting vertically tends to equalise these amounts, by being added at the outer or upper end and deducted at the lower end. For this reason, and on account of the more correct support of the cylinder and the absence of overhanging strains, that form of engine seems preferable for the highest speeds.

Condenser and Air-Pump.—In the arrangement of the condenser and air-pump the object has been to meet the difficulty of combining the advantage of a simple direct-acting air-pump with the very unusually high speed of working, 200 revolutions per minute. This has been effected with complete success by the construction adopted; a vacuum of 27 inches of mercury is maintained with great steadiness, and the air-pump works quite quietly and without noise at the full speed, and keeps thoroughly in order without requiring any attention.

The air-pump, as shown in Figs. 1 and 2 and in the transverse section, Fig. 7, Plate 12, is a nearly cubical box filled with water, with a plunger working through a stuffing-box in the lower part; the plunger is attached to the piston-rod and forms a continuation of it. The end of the plunger is made of a parabolic shape, as shown in Fig. 1, for displacing the water easily; and the plunger works entirely immersed in the water, simply displacing its own bulk of water at each stroke.

The inlet and outlet valves are all placed in the top plate of the box in two parallel rows, three inlet valves in one row and three outlet valves in the other, as shown in the plan, Fig. 2. They are india-rubber disc-valves with 8 inches diameter of opening, Fig. 7, and slide parallel upon their centre spindles without any bending of the india-rubber, being fitted with a metal plate and a long centre bush to guide the discs steadily in opening and closing, and to prevent any wear upon the edge of the india-rubber. The lift of the valves is about $\frac{1}{2}$ inch, and in order to obtain a quick action in closing they are closed by spiral springs, which load the valves to the extent of $\frac{1}{4}$ lb. per square inch. These springs are found

necessary upon the outlet valves as well as the inlet, in consequence of the quickness of the action required to close them 200 times per minute; and it was found that even at the speed of 120 times per minute there was a loss of 1 lb. per inch in the vacuum when the springs were not used, from the valves not closing promptly enough.

The condenser forms one half of the chamber above the air-pump, and the hot-well the other half, as shown in Fig. 7. The injection is introduced by a single opening in the centre of the condenser, with the full area of the pipe, in order to avoid any risk of the injection opening getting contracted by accumulation of deposit in a spreader or rose; and it has been found that no perceptible difference is caused by this arrangement in the vacuum obtained with the injection. In consequence of the position of the valves in the top plate of the air-pump chamber, the air entering from the condenser does not pass through the water, but simply passes over the surface of the water from the inlet to the outlet valves; and the water rising up to the outlet valves at each stroke ensures the discharge of the whole of the air. As no air gets to the lower portion of the air-pump chamber, the plunger works always in solid water, avoiding any churning action of mixed water and air; and indeed the effective piston of the air-pump may be considered to be, not the plunger, but the surface of the body of water that always remains in the air-pump chamber, which rises and falls at each stroke of the pump through a distance of less than one inch. The working velocity of the air-pump piston is therefore reduced in effect to only about 30 feet per minute, instead of 800 feet per minute the actual velocity of the plunger.

For the purpose of facilitating the passage of the air from the inlet to the outlet valves, the former are set at a small inclination below the horizontal position, as shown in Fig. 7, this idea having been suggested by a marine engine of Messrs. Maudslay and Field. The arrangement and position of this condenser and air-pump are very convenient for access to all the parts, the whole being above ground and at the level of the engine. It is held steady in its position by a connecting tie to the frame below and by the fixing of the exhaust-pipe above; and it serves as an additional guide for the smooth working of the piston-rod beyond the cylinder. The weight

of the plunger moving at the full velocity of the piston serves also as an important addition to the compensating action of the inertia at the commencement and end of each stroke.

Governor.—The expansion gear of the engine is regulated entirely by the self-acting movement of the governor, Figs. 1 and 2; and for carrying this plan out satisfactorily it is essential to have a governor that is extremely sensitive to any change of velocity, and acts with great promptness upon the expansion gear, with power sufficient to shift it instantly to the full extent required. The governor used for the purpose has been designed by the writer as a modification of the ordinary Watt centrifugal governor, with the view of increasing its sensitiveness and quickness of action, and adding to the power available for overcoming the resistance of the valve motion. This resistance is however reduced to a very small amount in the present engine, on account of the valves being in equilibrium.

The governor is shown in Figs. 8 and 9, Plate 13, and consists of two revolving balls of small size, but moving at a high velocity, which pull up a heavy central weight, when they rise in consequence of an increased velocity of revolution; the balls are only about 2 to 3 lbs. weight, but the central weight is from 50 to 300 lbs. according to the size of the governor. The connection of the radius rods to the centre spindle is made with forked ends having considerable width of fork, as shown in Fig. 8, and fitting upon a pin which passes through the axis of rotation, Fig. 9. The friction which opposes the rise and fall of the balls is thus reduced, by the pressure upon the pin at the joints of the rods being diminished in consequence of their increased leverage; and the sensitiveness of the governor is thereby increased, its friction being much less than that of the ordinary governor.

With the very heavy revolving balls employed in the ordinary construction of governor, a large amount of resistance is opposed by their inertia when they are required to act by rising or falling, on the occurrence of a change in the velocity of revolution. A serious pressure is also caused on the joints of the radius rods when the inertia of heavy balls of 1 cwt. each has to be overcome in order to

accelerate their motion; and the friction caused by this pressure on the joints prevents the change of position of the balls, until a sufficient increase of velocity has occurred to accumulate force enough for overcoming this resistance. The engine is thus allowed to vary considerably in speed; and the balls of the governor are then liable to fly out too far, causing too great an action for properly regulating the speed of the engine. In the present governor the revolving balls being of very small weight offer little resistance by their inertia to any change, and they rise or fall instantly when any change takes place in the speed of revolution of the engine. Their centrifugal force is made up to that of the ordinary heavy balls by their increased velocity of revolution, the centrifugal force increasing as the square of the velocity; and they are driven at a speed of from 320 to 400 revolutions per minute.

This governor is liable to the same objection in principle as the ordinary Watt centrifugal governor, namely that it can only regulate the engine for a variation of load by maintaining a corresponding change of velocity in the engine; but in this governor the action is so much more sensitive and extended than in the ordinary governor that this objection is practically got rid of. It is found to regulate the speed of the engine with certainty within the range of 2 per cent. variation of speed, with the greatest extent of variation that can occur in the load; and a variation in speed of 5 per cent. would carry the governor through its entire range of action, and shut off the steam from the engine. In practice the steam stop-valve is always set wide open, and the engine runs under all circumstances with complete steadiness and uniformity of motion, without requiring any attention; and the most sudden and extreme changes of load do not affect its motion perceptibly.

Special Construction.—In practically carrying out the high speed of working that has been adopted in this engine, special attention has been required to ensure the rigidity of both the stationary and the moving parts, to balance the forces of the moving parts, and to obtain a large extent of hardened rubbing surface, with perfect truth of form in the wearing parts. When due attention is paid to these points it

is found that there is no practical difficulty attending the employment of the high speed; and the objections ordinarily felt to it arise really from imperfections of construction in these respects.

For the purpose of obtaining the required rigidity in this engine, the base-plate is made a hollow casting of great stiffness and unusual depth, and the centre line of strain of the engine is brought down very near to its surface. The cylinder is bolted to the end of the base-plate, and is held all round the circumference of its inner end; but it is left free from the base-plate throughout its entire length. The object of this arrangement is to leave the cylinder free to expand and contract, without the tendency to distortion which arises when the cylinder is fixed down throughout one side to a cold base-plate, whilst kept heated along the other side by the steam-chest. The cylinder thus preserves its parallelism when at work, so that a deep and well fitted piston can be used; the piston employed is a plain hollow block, turned a close fit to the cylinder, and fitted with two Ramsbottom rings. The result is that, instead of the injurious wear often experienced in horizontal cylinders working at the lower speeds, the cylinders of these engines are found to be always in a polished and greasy condition, and their wear is inappreciable.

In all the working parts of the engine the bearings are made both unusually long and large in diameter, and by this means the pressure per square inch on the bearing surfaces is diminished, so that a thicker film of oil is maintained between them, reducing the coefficient of friction. The smoothness of running is thus increased also, by avoiding the injurious effects that arise from the bearings not having sufficient rigidity to resist flexure or torsion. In all the bearings special care is taken to obtain perfect truth of form, which is a point of great practical importance; and if properly formed and hardened these bearings should not be subjected to wear at all. The difference in working is remarkable between a true cylindrical form and such an approximation to it as can be produced by turning in a good lathe. When a truly cylindrical journal or pin has been produced by the operation of grinding with a traversing wheel, in dead centres which have themselves been ground to true cones, such a cylinder, if it has

sufficient surface and rigidity and is fitted in proper bearings, floats in an oil bath, being separated from the bearings at every point by a film of oil of exactly uniform thickness; this film cannot anywhere be broken, and having scarcely any disposition to work out will last without renewal for a great length of time; and the coefficient of friction under pressure is thereby greatly diminished. This truth of form is really easy of attainment, and if its value were fully appreciated it would certainly be obtained in general practice.

Mr. PORTER said he had hoped to be able to give the results of a series of comparative trials with one of the Allen engines, as compared with an ordinary engine of good construction and of the same power, working under the same circumstances. It had unfortunately been impracticable however to get these trials carried out yet; but it was intended to proceed with a very thorough set of experiments for this purpose.

Mr. E. A. COWPER enquired what were the particulars of the ordinary engine, with which it was proposed to compare the Allen engine in the experiments; whether it was provided with a separate expansion slide-valve, and what was the degree of expansion employed, and also what was the construction of the air-pump, and whether the cylinder had a steam jacket.

Mr. PORTER replied that the other engine was an ordinary horizontal high-pressure engine with an 18 inch cylinder, which had previously driven the shop for three years at the Whitworth Co.'s works, and it had been fitted with a condenser and air-pump exactly the same as those of the Allen engine; so that the comparison would not be complicated by the degree of condensation or the power required to work the air-pump. The cylinder of the engine had not a steam jacket. The steam was cut off at half stroke, and the slide-valve was an ordinary slide cutting off by the lap, without a separate cut-off slide on the back: the object being to make a comparison

between the Allen valve motion with variable expansion regulated by the governor, and the ordinary slide-valve worked by a single eccentric, with the governor acting upon the throttle-valve in the steam pipe.

Mr. E. A. Cowper thought that for a satisfactory comparison the ordinary engine should be furnished with a separate expansion valve, as was now the common practice in good engines, and also the cylinder should be provided with a steam jacket.

Mr. C. W. Siemens remarked that, as the value of any comparison between the Allen engine and an ordinary engine would depend altogether upon the particular condition of the latter, it would be much better to have the results of the Allen engine stated independently, giving the consumption of steam per horse power of the work done; this would afford the means of comparing the performance generally with that of any other engines. He was much struck with the very complete manner in which the various mechanical details in the construction of the engine had been worked out; and by the plan of carefully adjusting the weight of the reciprocating parts, so that their inertia at the commencement of the stroke should just counterbalance the highest steam pressure, there was no doubt that a very perfect result would be obtained, provided the speed was always maintained at the full rate upon which the calculation of the inertia was based. The main question he thought was whether the original fine adjustment of the working faces, particularly of the cylinder and slide-valves, could be practically maintained in continued work at the high speed at which the engine had to run; for although the wear of these surfaces might be reduced to a very great extent even at such a high speed, by great care in working and by the use of steam perfectly free from priming, yet it was hardly to be expected that these conditions could be constantly ensured in actual working for a length of time. It was therefore desirable to ascertain by actual observation what would be the result of continued working with a full load upon the engine. In the engine exhibited last year in Paris it appeared the bearing surfaces had not been altogether suited for the heavy load for which the power of the engine was calculated; and the results of the trials

with that engine had not been so satisfactory as they would have been, if care had been taken to increase the extent of the bearing surfaces in proportion to the load put upon the engine.

The governor described in the paper would he thought certainly be quicker in its action than the ordinary arrangement; and no doubt if an ordinary ball governor were weighted down in a similar manner by a weight or a spring, and had its speed accelerated to the same extent, its quickness of action would be correspondingly increased. The improved governor was in fact a Watt governor revolving at a higher speed; and it was therefore necessarily subject to the defects attending the principle of that governor, namely that at the moment when the engine began to change its speed the governor was without any power to act upon the valve, and it had then to accumulate power itself before it could control the engine. He should have felt some hesitation in going to such a high speed with the revolving ball governor, for fear of rapid wear and tear; but this was a point which would be decided by the results of actual working.

Mr. F. W. Webb concurred in the opinion that the most useful criterion of the economy of the Allen engine would be the actual consumption of fuel per horse power; and from his own experience of high speeds he agreed in thinking there would be a difficulty in maintaining the wearing surfaces of the slide-valves and cylinder, so as to keep them steam-tight in continued working.

Mr. E. Reynolds said he had seen the Allen engine at work at Manchester on several occasions, and he had also seen the ordinary engine that had been mentioned, with which it was proposed to make the comparative trial; and from the results said to be obtained with it he thought the latter might be taken as a very favourable example of an ordinary condensing engine. Simplicity of construction was a very important consideration in an engine for common use; and if an ordinary horizontal condensing engine, with a single slide-valve cutting off at half stroke, without a separate expansion valve, and without superheating the steam, could be made to work with 3 lbs. of coal per horse power per hour, which he understood was the case at the Whitworth Co.'s works, a very high result was attained.

The effect of the inertia of the reciprocating parts was a matter of great practical importance in any high-speed engine; and although the general principle had long been admitted, it did not appear to have been fully understood previously, and at any rate had not been fully acted upon in practice hitherto. In the present instance the effect of that inertia appeared to have been arrived at by a tentative process, by calculating the amounts of acceleration and retardation through each degree of revolution of the crank, and then the forces necessary to produce them. The simple way however to calculate the actual effect produced upon the crank pin by the inertia of the reciprocating parts in a horizontal engine seemed to him to be by supposing the whole weight of the horizontal reciprocating parts to be concentrated at the crank pin; and the centrifugal force due to the revolution of this weight in the circle of the crank being then resolved at any point of the circle into the vertical and horizontal directions, he considered that the horizontal component would represent the actual effect produced upon the crank pin at that point by the inertia attending the horizontal reciprocation of the same weight if accelerated and retarded in precisely the same degree and manner, though having horizontal motion only. In this mode of calculation the line representing the force necessary to produce the acceleration of the reciprocating parts by the crank in the first half of the stroke and their retardation in the latter half, during equal spaces passed through by the piston, would be a straight line corresponding with that described in the paper and shown in the diagram (Fig. 17), for a connecting-rod of infinite length; the maximum effect upon the crank pin being at the commencement and end of the stroke, at the moment when the crank was passing the centre, while the effect of the inertia became nothing at the middle point of the stroke. The effect of taking into account the length of the connecting-rod would be obtained by considering in an exactly similar manner the centrifugal force due to the angular motion of the rod in its arc of vibration, the horizontal component of which at every point of the stroke would have to be added in the outer half of the stroke to that previously ascertained with an infinite length of rod, and deducted in the inner

half. At the two extremities of the stroke therefore, the lineal velocity of the crank pin in its circle of revolution and of the connecting-rod end in its arc of vibration being at that moment identical, the amounts of centrifugal force due to the crank and to the connecting-rod would be in the inverse ratio of their lengths; and in the case of a connecting-rod having six times the length of the crank, the centrifugal force due to the connecting-rod would thus cause an addition or deduction of one-sixth upon that due to the crank. The total pressure produced on the crank pin by the inertia of the reciprocating parts would accordingly be seven-sixths at the outer extremity of the stroke and five-sixths at the inner extremity, in comparison with the equal pressure at both ends due to a connecting-rod of infinite length; thus giving a difference of $16\frac{2}{3}$ per cent. above and below the mean of the two, which was the same result as that obtained in the paper by a different method of calculation. On account of this difference it was clear that no single counterbalance weight, such as that added upon the driving wheel of a locomotive engine, could accomplish a true balance throughout the whole stroke; the utmost that could be done by such means was to balance the mean inertia, leaving the variation between the two extremities of the stroke without compensation. Although with the proportions and counterweights adopted in most engines at the present time this variation was not so considerable as to be of much importance, he thought it was still worth while to draw attention to the fact, in order to show the futility of attempting an absolutely true balance. This attempt had been made in the "duplex" locomotive engine shown at the International Exhibition in 1862 (see Proceedings Inst. M. E. 1863, page 97), one piston at one end of the stroke being intended to balance the other piston at the opposite end. But even in that case, though the difference in pressure of the wheels upon the rails due to the vertical action of a revolving counterweight in the wheel was avoided, yet the inequality in the inertia in the two halves of the stroke was still left untouched; as was also the vertical pressure of the crossheads against the slide-bars, tending to lift the two sides of the engine alternately: and no nearer approximation to a true balance was really effected than in ordinary engines having counterweights

attached to the wheels. In locomotives, in consequence of the variable speed as well as this difficulty in balancing, he thought the best mode of attaining steadiness in running was to keep the pistons and other reciprocating parts as light as possible; but in stationary engines intended to run constantly at a given uniform speed, it was most advantageous, as shown in the paper, that these parts should have a considerable amount of weight, so as to give the amount of inertia calculated to correspond with the standard speed of working.

The importance of bestowing sufficient attention upon the details of an engine appeared to him to be well illustrated by the working of the Allen engine at Messrs. Pooley's cotton mill in Manchester, which he had recently seen at work doing a heavy duty perfectly well, and with complete freedom from any signs of heating or undue strain. In general when it had been attempted to run a horizontal engine continuously at a high speed under a heavy load, the result had been that the bearings became very hot, unless a great deal of play were allowed; and on this account all previous attempts that he was acquainted with of running such engines at a speed anything like 600 feet per minute of the piston had been attended with much trouble and annoyance. At that speed however, and even higher speeds, the Allen engine worked quite comfortably, owing probably in a great measure to the special care taken to provide ample bearing surfaces and to get them up truly cylindrical. Another part of the engine which had been well worked out in the details was the air-pump. There was perhaps nothing strictly new in the plan of air-pump adopted for the Allen engine, as the importance of getting a large extent of surface for the water with small extent of motion had been previously advocated, instead of having the area of the water surface only the same as the area of the piston, as in ordinary air-pumps; nevertheless high-speed air-pumps had always been a difficulty, as shown by the violent oscillations of the vacuum gauge even under the best arrangements previously tried. In the ordinary engine however which he had seen at the Whitworth Co.'s works, fitted with the improved air-pump described in the paper, the vacuum gauge remained remarkably steady with the cock wide open, even

when the engine was running at the high speed of 94 revolutions per minute; at that speed there was only a slight pulsation in the gauge, instead of the sudden oscillations which would be exhibited with an ordinary air-pump driven at a considerably lower speed. This result showed that attention to the details was of the highest importance for the efficient working of an engine; and the same remark applied to the plummer blocks for carrying the main driving shaft, which he thought were well arranged for getting over the difficulty often experienced in horizontal engines of avoiding horizontal play without inducing heating of the bearings.

In regard to the improved construction of governor described in the paper, he thought that although an ordinary Watt governor if loaded in the same proportion might theoretically be considered to be equivalent in action, yet in that case the friction on the collars would necessarily be so great as to require a very large power to drive it; whereas by the device of taking so much weight out of the balls themselves, and applying it instead in the shape of a central weight lifted by the toggle-joint, the inertia of the balls was so far reduced that they offered much less resistance to any rise or fall corresponding to a change of speed. A less amount of power would therefore produce a given rise of the light balls in the improved governor, though lifting a weight equal to that of the heavy balls in an ordinary governor. On this account, and considering also the other improvements in the detail of the governor, he could believe that the extreme variation of speed in an engine controlled by this governor would not exceed 2 per cent. Having himself used many of these governors, he had found their increased sensitiveness rendered the speed of the engines remarkably steady; and as a cheap and simple construction of governor, sufficient for all ordinary circumstances, he considered the improved arrangement was a very valuable contrivance.

The Chairman remarked that the consumption which had been mentioned of only 3 lbs. of coal per horse power per hour, by an engine expanding only twice, was a very remarkable result; he had never heard of such a performance before, and would be glad to know whether the statement had been verified.

Mr. E. Reynolds said that was stated to be the consumption of the ordinary engine at the Whitworth Co.'s works. It did not follow however that, because the slide-valve cut off at half stroke, the expansion was only twofold; for though the steam was throttled in the steam pipe, it had ample time to accumulate in the steam chest during the latter half of each stroke, after it was cut off from the cylinder; so that the full pressure of steam came upon the piston at the commencement of each stroke, and was very rapidly reduced as the stroke progressed by wire-drawing through the throttle-valve, in consequence of which the resulting indicator diagrams were not very different from those produced by true expansion with a considerably earlier cut-off.

Mr. Porter explained that the consumption of 3 lbs. of coal per indicated horse power per hour in the ordinary engine at the Whitworth Co.'s works was exclusive of raising steam at starting in the morning; the temperature of the feed-water supplied to the boiler during working was below 100° Fahr. This result had been obtained in a week's careful experiment, and he believed its accuracy was unquestionable. The fuel used was the ordinary Lancashire coal, which was so much inferior in heating power to the Welsh, that the consumption of 3 lbs. per indicated horse power would be equivalent to only about $2\frac{1}{2}$ lbs. of good Welsh coal.

Mr. E. A. Cowper remarked that he could not approve of the Allen engine, but on the present occasion he did not wish to go into the questions of the high speed of piston or details of the engine, and would only refer to the subject which had been alluded to of the plus and minus pressure exerted on the crank pin by the momentum of the reciprocating parts. When the velocity of the piston was changing from an accelerating to a diminishing velocity in the middle of the stroke, there was no plus or minus pressure on the crank pin; but when the crank had passed the end of the stroke and the velocity of the piston was increasing, there was a minus pressure, that is, a portion of the pressure of the steam on the piston was absorbed in getting up its velocity and was not at that time developed on the crank pin; and then again in the latter portion of the stroke there was a plus pressure or extra pressure on the

crank pin over and above the pressure of the steam, from the fact of the crank pin then retarding and changing the velocity of the piston. If the ordinates of this plus and minus pressure were set out to form a diagram, they would give a curve dying away to nothing at about half stroke.

He wished to enquire whether it was intended that, on account of the very high speed of piston in the Allen engine, a small-cylinder engine on that construction should be considered as one of large power.

Mr. L. Olrick said he had seen the Allen engine at work at the Paris Exhibition, and also the very excellent sectional working model that was shown there, which gave a very clear idea of the valve motion worked from the single eccentric. By the very simple and ingenious arrangement of the bell-crank levers working the two slides, the object was attained of a sharp cut-off, without contracting the port openings by the gradual closing of the valve, as was the case with an ordinary slide-valve driven by an eccentric; and a very free opening was afforded for the admission of the steam, which entered at four distinct places simultaneously; while the entire valve motion was worked by a single eccentric always in gear. In respect to the governor described in the paper, there could be no doubt that the chronometric governor of Mr. Siemens was quicker in action and the nearest approach to absolute perfection; that governor was however rather more complicated in construction, and the ball-governor now described was certainly very simple and sufficiently perfect for most ordinary engines; for although in principle it was a Watt governor and involved therefore the same fundamental defects, these were reduced to a very small actual amount, by the improved construction of the parts and the use of much lighter balls revolving at a much higher speed. By the working of the Allen engine the very high speed of piston mentioned in the paper had now been shown to be practicable, without involving the objections usually experienced hitherto in any attempts to increase the speed of piston considerably; and he thought the successful results now attained were satisfactorily accounted for by the explanation given in the paper, the weight of the reciprocating parts being augmented to such

an extent that their inertia entirely absorbed all the initial surplus pressure of the steam on the piston at the beginning of each stroke, thus relieving the crank pin from the usual great strain on the centres, which would otherwise be most dangerous with such quick-working engines. This principle having been so carefully carried out in the proportions adopted in the Allen engine rendered it a race-horse in speed as compared with ordinary engines; and for such an engine the lighter and more sensitive governor of Mr. Porter was excellently adapted. They were also indebted to him for the introduction into this country of the Richards indicator, the lighter and more sensitive construction of which rendered it the only instrument capable of giving a correct diagram from an engine running at a very high speed. The remarkable attention paid to the details in all the parts of the Allen engine might be imitated with great advantage he thought in all other descriptions of machinery, the ordinary turned bearings being only approximately cylindrical, and in reality more or less polygonal; but it was only in conjunction with ample extent of surface and perfectly round bearings that the high speeds of working described in the paper had been so successfully realised.

Mr. H. Woods asked if it was intended in the construction of the Allen engine in the future to discontinue the use of the steam jacket.

Mr. J. Fernie said he had seen the Allen engine when first shown at the 1862 Exhibition, and also the improved one at the Paris Exhibition and the one working in Manchester, and he had been much pleased with their performance; they were very steady at the great speed at which they ran, and seemed to do the work with remarkable ease. One reason of the smoothness of running was that there was no feed-pump attached to the engine, and the rattling action attendant upon a pump was thereby avoided. The speed of piston, although much higher than was usual in stationary engines, was not more than was general in locomotives; for a locomotive running at 40 to 50 miles an hour had a piston speed of about 600 feet per minute. With the adoption however of this high speed in stationary engines, he suggested that it would be very

desirable at the same time to increase the pressure of steam up to 100 or 150 lbs. per square inch, in accordance with the present practice in locomotives; if this were done, and the principles already carried out in the Allen engine were as carefully adhered to with the higher pressure, he thought the results obtained would be still more advantageous. He enquired what was the amount of lead given to the slide-valve, in working with the single eccentric; and also what was the practical advantage afforded by the engine, in respect to the proportion between the power obtained and the space occupied.

Mr. A. Coventry, having had several opportunities of seeing the Allen engine at work in Manchester and in London, considered the most distinctive feature about it was that it took up all the best points of other engines, and combined them in one engine. A quick cut-off was obtained, with a variable expansion regulated by the governor according to the load on the engine; at the same time the exhaust was invariable at all grades of expansion, and very free. It was also deserving of remark that for an engine combining all these advantages it contained the smallest possible number of parts.

Mr. Porter remarked that the piston speed of 800 feet per minute in the Allen engine at the Whitworth Co.'s works was considered exceptional; and the standard speed in calculating the proportions of the engine had been taken at 600 feet per minute. At the same time if a higher speed, even up to 1000 feet per minute, were desired for any special purpose, he should not hesitate to run the engine at that rate, with suitable modifications in the proportions of the parts.

In reference to the heating of one of the bearings in the engine at the Paris Exhibition, as mentioned in the paper, that was not owing to want of sufficient extent of surface, but was altogether an accident arising from an error in the bearing, which caused it to be imperfectly lubricated. The dimensions of the bearings were very large; and the engine at the Whitworth Co.'s works, with the same dimensions, had been working very satisfactorily under a load twice as heavy as that put upon the engine in Paris. With the ample extent of bearing surface that was provided, it had been

found that the engine was perfectly safe from heating, so long as uniform lubrication was ensured. On the engine at Manchester all risk of imperfect lubrication was prevented by the employment of a continuous mechanical lubricator, consisting of a brass cup fitted with a cock having a solid plug, in one side of which was drilled a hole large enough to hold a couple of drops of oil, so that at each revolution of the plug that quantity of oil was supplied to the crank pin; the plug was caused to revolve by means of a worm and wheel, actuated by a small cam let into the circumference of the crank-pin collar. In lubricating with the ordinary cotton wick as a syphon, it occasionally happened that the lubrication failed for a length of time without the defect being observed; but the mechanical lubricator had been found to remove that difficulty altogether.

The lead of the valves was necessarily considerable in running at a high speed, in order to afford a sufficient area of inlet for completely filling the port and clearance space at the commencement of each stroke; and in the original setting of the valves the lead was adjusted with reference to the indicator diagram, until a figure was obtained with a sufficiently square corner at the beginning of the stroke. The amount of lead thus arrived at was such that the steam could not be entirely shut off by the governor, when the work was thrown off the engine; but when the whole load was thrown off excepting only the main line of shafting driven by the engine, the admission of steam was so far reduced by the governor that no acceleration of speed took place in the engine.

For taking up the wear of the slide-valves the requisite means of accurate adjustment was provided in the manner described in the paper, by the insertion of packing strips underneath the supports of the cover-plate on the back of the valves; so that the rubbing faces could be let together at any time to the exact extent required, by simply reducing the thickness of these packing strips. The form of piston to be used was quite immaterial; the piston which he had employed was packed with two Ramsbottom rings, as shown in the drawing, and had been found quite satisfactory.

The governor controlling the Allen engine was absolutely the same in principle as the original Watt governor; but the object had been to obtain a nearer approach in practice to the degree of perfection of which that principle was capable. This was effected by reducing as far as possible the severe friction upon the joints, which exerted so great a retarding force upon the action of the ordinary governor; and a further step was the substitution of the central heavy weight, instead of putting the whole amount of weight into the revolving balls.

It was the consideration of the inertia of the reciprocating parts which he thought constituted the most important point in the construction of the Allen engine; and in the case of the engine at the Whitworth Co.'s works this consideration had justified the adoption of a mean initial steam pressure as high as 57 lbs. per square inch; but were it not for the compensating effect of the inertia of a heavy piston, it would be impossible for the crank pin to stand anything like such a pressure in an engine of that size. By the exact balancing of the initial pressure of steam and the inertia of the reciprocating parts an increased smoothness in running was obtained, and a gliding motion in passing the centres, instead of having a concussion upon the crank pin at these points.

The air-pump did not contain any entirely new features, but was simply a combination of all the best points in previous air-pumps, and he thought it was a very satisfactory solution of the question of working an air-pump in an engine running at a high speed. The vacuum constantly maintained at the speed of 94 revolutions per minute was $27\frac{1}{2}$ inches of mercury and often 28 inches; and even at 200 revolutions per minute the average vacuum was 26 inches. No trouble whatever had been experienced with the air-pump in regularly working at those high speeds.

The use of a steam-jacket he had been led to abandon in the case of small engines; for although it was unquestionably advantageous wherever there was abundant communication with the boiler, so as to get the full heat of the boiler steam in the jacket and allow the condensed water to drain back freely, yet in small engines there was much difficulty in ensuring these conditions being carried out. It

frequently happened indeed that, owing to the accumulation of water in the steam-jacket, the temperature surrounding the cylinder was considerably lower than that at which the steam entered the cylinder; and under such circumstances the jacket was of course an injury rather than a benefit. In expanding to a very great extent, such as cutting off the steam at 1-10th of the stroke, it was certainly impossible to work with advantage unless the cylinder was jacketted; but on the other hand he did not think it desirable in practice to cut off the steam so early as 1-10th, and he considered a cut off at 1-6th or 1-5th was the earliest that was advisable. Although expansion had great advantages in economy of fuel, it might be overdone, if the limits assigned by other considerations were not attended to.

The degree of accuracy of work required in an engine running at the high speeds named in the paper was nothing more than the best makers of engines and machinery were now thoroughly accustomed to; what would be considered reasonably good work for other similar purposes would do very well for a high-speed engine; but of course any errors arising from inferior work were sooner detected by the high speed, and their evil effects aggravated. In the case of the Allen engine at the Whitworth Co.'s works, the result of the large extent of the wearing surfaces and the excellence of the work had been that, after running constantly for several months, there was absolutely no wear about it at all: the cylinder and slide-valve faces were perfectly smooth, and the guide bars still showed the original marks of the scraping tool.

The commercial benefits attending the Allen engine were not so important a subject for consideration, he thought, as its mechanical advantages; and a reasonably high speed had a great many advantages for stationary engines besides the saving of space and the economy in first cost. In the present instance, with the high speed now employed, the engine had only a single cylinder instead of two cylinders coupled at right angles, and yet gave the same uniformity of motion; it was also a horizontal engine instead of a beam engine, and a simple engine instead of a compound one.

The pressure of steam employed in the Allen engine at the Whitworth Co.'s works, namely 57 lbs. per. square inch, although

higher than hitherto commonly adopted in condensing stationary engines, was by no means so high as he thought might with advantage be used; and he agreed in considering that the higher the pressure, the better would be the results obtained from the engine. The proportions of the several parts would of course have to be modified for an increase of pressure beyond certain limits; and the engines could be constructed to work at any steam pressure that might be desired. The number of separate parts contained in the engine was on the whole smaller, as had been noticed, than in an ordinary engine of the same power; and the same remark applied even more forcibly to the number of working joints in the engine. The joints in the valve gear, which were frequently a source of trouble in other engines, appeared in this to be absolutely free from wear, and had never given the slightest trouble. The air-pump being here worked direct from the piston-rod of the steam cylinder was without any joints at all; whereas in an ordinary engine there were commonly several joints involved in the connection for driving the air-pump.

The Chairman proposed a vote of thanks to Mr. Porter for his paper, which was passed.

The following paper was then read:—

DESCRIPTION OF THE AMERICAN DOVETAILING MACHINE.

By Mr. JOHN ROBINSON, of Rochdale.

This Dovetailing Machine, which is the invention of Mr. S. T. Armstrong of New York, was shown at work at the recent Paris Exhibition. It is constructed so as to cut out the dovetail joints in woodwork by means of the continuous rotation of compound circular saws of peculiar form, which finish the joints completely, without the use of any chisels or cutters, as was requisite in previous machines for the purpose. The same machine cuts both the pins and the holes of the dovetails in succession, by a simple change of adjustment, so that their pitch and dimensions necessarily correspond exactly, and make a correct joint in every case.

The machine is shown in Figs. 1 to 5, Plates 21 to 24; Fig. 1 is a side elevation, Fig. 2 a back elevation, and Fig. 3 a plan.

The two compound circular saws A and B, each about 2 feet diameter, are placed inclined to one another at an angle of 18°, Figs. 2 and 3, corresponding to the inclination of the two sides of the dovetail pins; and they are geared together by two bevilled toothed rings upon their inner faces. The saws run loosely upon two short fixed axes; and one of them A is driven by the main driving shaft C through the intermediate bevil wheel D, which gears into a corresponding toothed ring on the outer face of that saw; the second saw B is driven by the first one A.

The two inclined axes of the saws, one of which is shown separately at E in the section, Fig. 5, Plate 24, are fixed upon the faces of two small circular discs F; these discs are parallel

to one another, and each has a spindle G on the outer face. The two spindles are both in the line of the driving shaft C, and turn in two sockets in the machine frame. The discs F F have two toothed sectors I I fixed upon them, which gear with two pinions on the shaft J J, so that on turning this shaft by the handle H the inclined axes of the two saws are turned round simultaneously through a quarter revolution ; the direction of their inclination is thus changed from vertical to horizontal or the reverse, and the point of contact of the two saws is rolled round through a quarter of a revolution. The connection with the driving shaft C for driving the saws is preserved during this change of position by the intermediate bevil wheel D continuing in gear, whilst rolling round into the position shown by the dotted lines in Figs. 1 and 2, the wheel D being carried upon the arm of one of the toothed sectors I.

The object of this movement is to change the action of the saws from cutting the pins to cutting the holes of the dovetails. The wood to be cut is clamped down upon the table K, Figs. 1 and 3, which is placed radially to the saws, so that the cuts are at right angles to the face of the wood ; and when the dovetail holes are to be cut, the two saws are required to be at their full inclination to each other in plan, but parallel on the edge of the wood, as shown in Figs. 8 and 9, Plate 25, so that one saw cuts the right-hand side and the other the left-hand side of each dovetail hole ; and the two oblique axes of the saws are made for this purpose at the inclination to give the angle of 18° between the two saw faces. But when a rotation of a quarter of a circle is given to these two axes by means of the toothed sectors I I, the direction of their inclinations is then brought at right angles to the face of the wood to be cut, as shown in Figs. 6 and 7 ; and the edges of the saws, where in contact with the wood, are parallel to one another in plan but inclined in elevation, so as to cut the dovetail pins with parallel sides on the face of the wood, Fig. 6, but inclined on the edge of the wood, Fig. 7. By this means the pins and holes of the dovetails are formed at exactly the same inclination, by the simple expedient of cutting

them at two different points of the circumference of the saws, at right angles to each other.

Each saw cuts one half of a pin or hole in a single revolution. The saw blade is made plain for the first three-quarters of its circumference, like an ordinary circular saw, but with a spiral outline gradually increasing in diameter, as shown in Fig. 4, Plate 24, so as to increase the depth of cut continuously until the bottom of the dovetail is reached. The last quarter circumference of the saw blade is made truly circular, but has the cutting edge bent over at right angles, so as to cut at the side, for cross-cutting the bottom of the dovetail; and the lateral projection of the flanged blade gradually increases until it is equal to half the width of the bottom of the hole. For cutting the pins of the dovetail, the two saws being then parallel in plan, as shown in Fig. 6, Plate 25, the flanged saw blades have the edge bent over inwards exactly at right angles, for cross-cutting the bottom of the dovetail; but for cutting the holes, the flanged blades are bent over outwards to an angle of 81°, as shown in Fig. 8, the two saws being then inclined at 18° towards each other in plan.

In order to traverse the wood for obtaining a succession of cuts, the table K on which it is clamped is traversed across in front of the saws with a continuous feed motion by means of the bed-screw L, Figs. 1 and 3, driven by spur gear from the main shaft C; and the blade of each saw, instead of being at right angles to the axis upon which the saw revolves, is set inclined like a screw thread, with 1 inch pitch, that being the intended pitch of the dovetails. The bed-screw L also traverses the wood 1 inch forwards in each revolution of the saws; and the saws and the wood are consequently made to traverse exactly together, each saw following up its own cut correctly, until the cut is completed at the end of one revolution of the saw; and the saw then commences the next cut at the pitch of 1 inch. The second saw B does not commence cutting until the first saw A has advanced a certain distance in the work, as shown in Figs. 6 to

13; and it continues cutting throughout at the same distance behind the first saw, but completes all the pins or holes at the end.

The saw blades are made in short segments, each 6 inches long, as shown in Fig. 4, and are fixed in their places by fitting into a turned recess M M in the circumference of the cast-iron boss B; they are held in their places by a series of segment plates N N at the back, tightened up by two bolts each. The saw segments are readily released and changed, when it is required to set the machine for a different size of dovetail, or to change from cutting the pins to cutting the holes; and five different sets of blades are kept for this purpose, to give the extent of range in dimensions of dovetails that is required with each machine; the several sets vary proportionately both in the plain and the flanged portions of the blade.

In changing the machine from cutting the holes to cutting the pins of the dovetails, the two saw blades require a slight adjustment endways relatively to each other, in order to take up the slack that would be caused in the fit of the dovetails by the thickness of the saw-cuts themselves, and to make the pins fit true and tight in the holes without any shake. This adjustment is obtained by simply rotating the second saw B a certain distance round upon its axis E, Fig. 5, the toothed driving ring R R being for this purpose made loose upon the boss B of the saw, and locked to it by the pin P for driving the saw. As the circumference of the saw blade is itself in the form of a screw thread of 1 inch pitch, the effect of turning the saw round upon its axis E is to shift endways the point of commencing the cut; and by this means therefore the cut of the second saw is made to follow that of the first at exactly the required distance. The ring R R, Fig. 4, is marked with graduations corresponding to the several adjustments required for changing the machine from one size of dovetail to another, or from cutting the pins to cutting the holes of the dovetails; and the adjustment includes the required allowance for clearance, to make the pins and holes fit together with any degree of tightness that is desired, without requiring any dressing by hand. The whole change is so readily made

that in three minutes the machine can be altered from one size of dovetail to another, and got to work again.

The saw segments are all made exact duplicates of one another in the portions fitting on the boss of the saws; and consequently in the wear of the saws, as the segments become gradually reduced in diameter by the sharpening, they are simply shifted each to the adjoining place in the circumference of the saws, a new segment being required only for replacing the last or largest flanged segment. The change also from the flanged to the plain segments is made by filing down plain teeth in the first flanged segment when worn out.

The table K carrying the wood, Fig. 1, is made with a hinge movement, so that it can be inclined at an angle of 45° to its usual radial position, as shown by the dotted lines at T, for the purpose of cutting concealed dovetails, in which the two pieces of wood form a mitre joint at the outer angle, the dovetails being concealed, as shown in Figs. 10 to 13. No other alteration of the machine is required for this work, as the bottoms of the pins and holes are then finished correctly at 45° by the cut of the saws.

The table K is mounted upon two slides at right angles to each other, like the slide-rest of a lathe; the lower slide receives the traverse feed-motion from the bed-screw L, and the upper slide is moved inwards towards the saws by the hand lever U, Figs. 1 and 3, through a distance equal to the depth of the dovetails. The upper slide also carries a half nut, which gears with the traverse screw L; so that when the wood is advanced up to the saws by the hand lever U, the nut is at the same time thrown into gear with the screw L, causing the traverse feed-motion of the wood to commence.

A scriber S, Figs. 1 and 3, is used to mark off on the underside of the wood the bottom line of the dovetail pins and holes, in advance of the saws, to prevent the edge of the wood from being broken on the underside. This scriber serves also as a gauge for setting the edge of the wood to be cut, which is first clamped down upon the table K with its edge level with the scriber S, Fig. 3; and the wood being then moved inwards towards the saws by the hand lever U, this gives the correct depth of cut for the dovetails.

The working speed of the machine is 150 revolutions per minute, one pin or hole of the dovetail being cut at each revolution.

Mr. Robinson exhibited one of the circular saws complete from the dovetailing machine, and also a number of specimens of the dovetails cut by the machine, showing the several stages of the operation, in the case both of ordinary dovetails, and concealed dovetails for such purposes as cabinet makers' work.

The Chairman enquired whether the specimens of dovetails exhibited had been dressed by hand after leaving the machine, in order to make them fit together so true and tight.

Mr. Robinson replied that none of the work had been touched at all by hand, and it was exactly as it came from the machine. The fit of the joints was readily adjusted by the machine to any degree of tightness that was desired, by simply turning the second saw upon its own axis through a smaller or larger arc, at the time of changing from cutting the pins to cutting the holes; by this means the fit was made much more correct and uniform than was possible in any hand work.

Mr. H. Chapman enquired whether the machine was found to answer for cutting hard woods, and what was the hardest wood that had been tried.

Mr. Robinson replied that the hardest wood in which he had cut dovetails by the machine was elm, which when dry was very hard; and in the hard woods the work was cut still cleaner than in the softer woods. The specimens exhibited were all cut in deal, for the purpose of showing the character of the ordinary work produced by the machine, which was mainly employed upon deal for making packing-cases and other large boxes.

Mr. E. A. Cowper said he had seen the working of one of these machines in London, and an important advantage obtained in that mode of cutting dovetails was that the strength of the joint was

greatly increased, and in fact the maximum strength was got out of the material, because the dovetails and recesses could be spaced uniformly along the entire line of the joint, so as to make the dovetails as wide as the spaces, instead of having only a few small dovetails placed wide apart, as was often the case in joints dovetailed by hand. The construction of the machine indeed prevented any undue width of spaces being left between the pins; and the spacing to which the machine was originally adjusted was continued with complete uniformity through the whole of the work. In regard to hard woods he believed the difficulty experienced in previous dovetailing machines had been that the hard wood could not be cut without splitting it; in the present machine it appeared that the first three-quarters of the circumference of the saw blade was employed in cutting the depth of the dovetail, and only the last quarter was left for doing the whole of the cross-cutting; and he suggested that for cutting hard woods it might perhaps be desirable to have a greater length of the circumference flanged over for the cross-cutting, so that there should be less work upon each tooth of the saw, thereby giving a smoother cut in the wood. The plan of flanging the saw blade at right angles for cross-cutting the bottom of the dovetails was certainly a very ingenious idea; as was also the arrangement for allowing the work to be traversed continuously through the machine, by making the saw blade inclined like a screw thread, so as to follow the traverse of the work whilst cutting the dovetail at the same time; and this he considered the great novelty of the machine. The mode of fixing the segmental saw blades afforded great facility for changing them for a different set whenever required; and he had seen the entire set of blades in the pair of saws taken out in $1\frac{3}{4}$ minutes, and a new set put in and fixed in 2 minutes more, ready for the machine to start working again. The machine was altogether most ingeniously contrived, and he thought it would be found very useful and efficient, particularly for making packing-cases and boxes, as the wood might be made thinner, and yet the same strength be obtained at the joints.

The Chairman enquired where the flanged saw blades were made that were required for the cross-cutting. He asked also whether the

machine was extensively used in America, having originated in that country.

Mr. Robinson replied that he was informed there were now more than 2000 of these machines at work in America. The saw blades, both plain and flanged, were made at his own works by the same men who fitted the machines together; and in reference to the greater amount of work put upon the teeth in cross-cutting in hard woods, it was not necessary to use a greater arc of the circumference for the cross-cutting in that case, but it was only a question of the increased fineness of the saw teeth; and with teeth sufficiently fine the cut was made smooth and clean, without any risk of splitting the wood. The saw teeth were required of course to be particularly well tempered for working in hard woods; and the machine had done a great deal of work in cutting dovetails in hard wood.

The Chairman moved a vote of thanks to Mr. Robinson for his paper, which was passed.

The following paper, communicated through Mr. C. William Siemens, was then read:—

ON AN IMPROVED CUPOLA FOR IRON FOUNDRIES.

By Mr. JACOB EICHHORN, of London.

In Cupola furnaces the blast enters generally either through tuyeres, or through horizontal or vertical slits at the sides of the cupola; but a disadvantage attends these arrangements, inasmuch as the blast being too cold at the beginning to combine at once with the carbon of the fuel, must first be diffused through the fuel before it can burn, and the greatest heat is therefore produced at a point situated above the tuyeres. The height of this point varies with the respective quantities of fuel and of blast that are introduced; and when sufficient fuel is supplied, the point of greatest heat will be situated at the level where all the oxygen in the blast has become carbonic oxide. It is found in practice that the range of level of this point extends over several feet, according to the quantity of fuel used, the height being generally about 3 feet above the level of the tuyeres; but in the cases mostly met with in foundries there is not a sufficient supply of fuel close to the tuyeres or openings where the blast enters, and in these cases therefore the blast does not meet with sufficient fuel for complete combustion until it arrives at the upper layers of the fuel, and it consequently passes the hot metal and causes it to be burnt. The waste upon the metal put into the cupola amounts to from 5 to 10 per cent. generally in these furnaces; and the rapid burning away and destruction of the lining extends over a height of 5 to 6 feet from the hearth. Another disadvantage, resulting from the necessarily confined space occupied by the tuyeres or blast openings, is that the blast, being thereby concentrated, acts upon the carbon contained in the iron, and consequently deprives the iron more or less of its fusibility.

To remove these disadvantages of the ordinary construction of cupolas, a plan has been devised and carried out successfully by Mr. Henry Krigar of Hanover, which forms the subject of the present paper, and aims at the accomplishment of the following objects :—to concentrate the heat in the lower part of the cupola, where there are facilities for easily repairing the furnace lining, and to render the action of the cupola uniform throughout the operation of melting; to give the hearth such a size that the column of fuel between the layer of melted metal and the level where the blast enters the interior of the furnace may vary but little in height, so as to limit the range of the destructive action upon the furnace lining; and to ensure the blast being taken up by the carbon of the fuel from the moment of its entering the furnace, and thereby prevent it from injuring the heated metal by oxidising it.

The construction of this cupola is shown in Figs. 1 to 5, Plates 26 to 29; Fig. 1 is a front elevation, Fig. 2 a vertical section from front to back, Fig. 3 a vertical section from side to side, and Figs. 4 and 5 are sectional plans at different levels.

The vertical shaft A A of the cupola is made rectangular in form, either square or oblong, as shown in the plan, Fig. 4, and parallel or with very little taper in height, so as to avoid any prominent part upon which the flame could strike, and which would be exposed to rapid destruction. A backing of sand is used behind the brickwork to concentrate the heat in the cupola. The shaft A is supported at front and back by arches B B over the lower chamber C C; and at the sides of this chamber is also a backing of sand, as shown in Fig. 3, to keep the heat in. Over this backing and round the bottom of the shaft A runs the air passage D D, into which the blast is delivered from the two air mains E E; and the blast entering through this passage cools the brickwork of the cupola, and becomes heated itself; it then passes down into the melting chamber C C through the two long slots F F in the roof, one at the front and the other at the back, extending the whole breadth of the hearth, as shown in the plans, Figs. 4 and 5. These slots are constructed by leaving a space of $4\frac{1}{2}$ inches width between the outer arches G G, Fig. 2, and the inner arches B B that carry the shaft A;

the length of the hearth H from front to back is consequently made greater than the breadth. The front of the cupola is closed by an iron door K on hinges, extending the whole breadth of the hearth; and a smaller door L is placed at the back, to facilitate the drawing of the cupola by inserting a rake at the back; by this means the drawing of the cupola can be accomplished regularly within 3 or 4 minutes.

For starting the cupola, about 1 to $1\frac{1}{2}$ cwt. of coke is placed on shavings or some burning coke upon the hearth, and more is added by degrees from the front door, until all the coke intended for the first filling is put in. The door K is then closed, being first wetted on the inside; and the tapping hole J is formed as usual by placing clay round a wetted stick. The whole height of the door is then plastered on the inside with a mixture of clay and sand, the door being set forwards about 5 inches in front of the breast of the furnace, to allow space enough at top for the furnace man to get his arm in for lining the door; and the space at top is afterwards closed with bricks. This mode of closing is adopted for cupolas working with a pressure of blast of from 4 to 7 inches of water; but where the blast is stronger a wall of coke is first built up inside the melting chamber C and wetted; and the door being shut and secured with wedges, the space between the door and the wall of coke is then filled with foundry sand rammed in.

The amount of filling that is put in for starting the cupola varies with the size of the cupola and the quantity of melted metal that the hearth is intended to contain at once; but the amount is always much less than is usually employed in other cupolas. One of the new cupolas capable of melting 3 tons of iron per hour requires a filling of $2\frac{3}{4}$ cwts. of coke for starting it, or $3\frac{3}{4}$ cwts. when it is intended to keep the whole of the melted metal in the hearth, to be tapped all at once. Upon this filling a charge of 8 cwts. of iron is added from the top of the cupola shaft, and then about $\frac{1}{2}$ cwt. of coke, and again a charge of 8 cwts. of iron followed by $\frac{1}{2}$ cwt. of coke; and the same in succession until the whole charge is put in, filling up the shaft A to the top, as shown in Fig. 2. After the casting, a certain quantity of the coke is drawn out unconsumed. The average quantity of coke

consumed is $1\frac{1}{2}$ cwt. or 168 lbs. per ton of iron melted, when only 3 tons are melted in each charge; and the consumption is 147 lbs. per ton when charges of 6 tons are melted; and 140 lbs. per ton with heavier charges.

The metal melted in this cupola is found to be very fluid; and indeed so fluid that, in the cases where in an ordinary cupola seldom more than one half of cast-iron scrap is used, this cupola bears under the same circumstances the addition of fully three quarters of scrap. At the same time the softness of the metal is retained; or, as it is commonly termed, the metal is clean. If the cupola be allowed to stand without blast for one hour after the filling is completed, and the blast be then turned on, the metal begins to run down to the tapping hole six minutes afterwards; but if the blast be admitted immediately on completion of the filling, without allowing the cupola to stand, the metal may be made to run from the tapping hole within one hour from the time that the cupola was empty before the filling commenced.

This cupola has the advantage of allowing the whole of the metal melted during one hour to be retained in the hearth; this result however is not obtained by increasing the height from the bottom of the hearth to the crown of the arches carrying the shaft, but by increasing the length of the hearth from front to back, as shown in the longitudinal section, Fig. 2. If the height from the bottom of the hearth to the arches is made too great, the metal loses the great fluidity that distinguishes the working of this cupola. The height from the tapping hole J to the charging opening at top of the shaft A is from 13 to 14 feet. As the construction of the cupola causes it to work hotter than ordinary cupolas, it requires a smaller area of shaft than an ordinary cupola for the same blast and yield, the reduction being in the proportion of about 3 to 7; any existing cupola shaft can therefore be altered to this plan, and will still yield more metal than before in the same time.

The quantity of blast required is 30 cubic feet per second, reduced to the pressure of the atmosphere, for each ton of iron melted per hour. The pressure of the blast used may be as low

as 4 to 5 inches, but a pressure of 8 or 9 inches is generally adopted. Whether this or a still higher pressure is used, no further economy of fuel is obtained, but only a greater quantity of metal is melted down in the same time by the same furnace.

With regard to the wear and tear of the cupola, the lower part of the shaft A is exposed to the greatest destruction, but that is the only portion which suffers more than the lining of an ordinary cupola, and it is easily accessible for repair. The coke falling from the shaft into the melting chamber C C, Fig. 2, stands there in a heap, upon which the blast rushes through the two transverse slots F F in the roof; and the heat from the burning fuel being radiated into the air passages D D, the blast becomes prepared for combining rapidly with the carbon of the fuel, before it has an opportunity of coming in contact with the melting metal and wasting it by oxidation; and the action of the blast is finished, as may be judged from the appearance of these cupolas, at a level of only about 14 inches above the crown of the arches B B. This corresponds to the portion of the cupola that requires to be renewed about every three to four months; and a small arched iron bar of 2 to 3 inches width, remaining constantly in its place in each arch B, allows of the arches being readily replaced at any time without the introduction of centering. The shaft A suffers very little wear itself, and after six months' work it can only be said that the bricks are strongly glazed. When the arches B B are replaced every three to four months, the face only requires patching or plastering up once or at most twice a week; and only about half or little more of the repairing material is required that would be necessary in an ordinary cupola. The total cost of wear and tear therefore does not at most exceed that of the ordinary cupolas, while there is less trouble in keeping the improved cupola in repair.

With regard to economy of metal, the results of the working of this cupola are found to be that in melting pig iron, such as Calder No. 1, the loss amounts to 3·4 per cent. on the metal weighed in; and when mixed with three fourths of railway-chair scrap, the loss only 2·2 per cent.

Mr. C. W. Siemens said that he had been much struck with the working of the new cupola on first seeing it several months ago; and the main feature in it which appeared to him of particular advantage was the improved mode of introducing the blast, through the air passages and arches at the bottom of the vertical shaft. In an ordinary cupola, when the blast went in straight through the tuyeres it met with the iron and the coke promiscuously, and the melted iron falling in drops into the hearth became oxidised or burnt by encountering the uncombined oxygen of the blast; the quantity of cinder on the top of the melted metal in the hearth was thereby increased, and metal wasted. In the new cupola however the blast on entering did not at once meet the iron, but it first came upon a heap of red-hot coke, by which the oxygen was partially converted into carbonic acid; and as this passed upwards through the ignited materials above, the greater portion took up a further supply of carbon from the coke, and became reduced to carbonic oxide, while only a small portion parted with some of its oxygen to the melted iron; the metal thus became less burnt than when exposed to the direct action of the uncombined oxygen in the blast. Another peculiarity of the new cupola was the large size of the hearth, on account of its increased breadth, which allowed of a large accumulation of melted metal being contained in the hearth, without increasing its distance below the level of the zone of greatest heat in the shaft of the cupola. The metal in the hearth was thus kept thoroughly hot, up to the time of tapping the cupola. As the combustion was completed so close to the bottom of the cupola shaft, the gases escaping from the top came off more thoroughly deprived of their heat than would otherwise be the case; so that the effect in that respect was similar to what would be obtained with an ordinary cupola of considerably greater height. The bottom of the vertical shaft was certainly more liable to suffer from wear and tear in this construction than in an ordinary cupola, because the arches were evidently exposed to a more severe action of the heat; and it would be necessary to ascertain by continued working what was the duration of this part of the cupola. The worn portions however were easily accessible for

repair; and the iron plates on which the arches were built remained uninjured, being themselves not exposed to the excessive heat.

Mr. F. W. Webb said he had used one of the improved cupolas at Bolton during the past few weeks for melting down iron for the Bessemer process, for which purpose the metal was required to be much hotter than for ordinary castings. The cupola was worked for tapping out 2 tons make of metal at once, and the fuel employed being Durham coke, the quantity required for filling in was $4\frac{1}{2}$ cwts.; after which the charges were alternately $7\frac{1}{2}$ cwts. of iron and 60 lbs. of coke until the charging was completed to the top of the cupola shaft. This gave the proportion of coke to iron as 1 to 14, neglecting the filling in; and when the cupola was raked out after tapping, some of the fuel remained available for use in filling in for the next charge. In one of the ordinary cupolas previously employed the consumption of fuel in working 6 ton charges was $4\frac{1}{2}$ cwts. per ton of iron, including the filling in, the fuel in that case being Lancashire coke from Accrington. The wear and tear in the new cupola he anticipated would be found to be rather greater at the bottom of the vertical shaft than seemed from the paper to be expected; but at present the cupola at Bolton was working very well, and one advantage found was that the iron was obtained very hot from it.

Mr. E. A. Cowper observed that he had seen the new cupola at work in London, and was very much pleased with it; and he thought the consumption arrived at of only 140 to 160 lbs. of fuel per ton of iron melted was really a very small amount. The lowest consumption that he was acquainted with previously in other cupolas was 2 cwts. of Elsecar coke per ton of iron; and that result was only obtained with a large cupola, 3 feet 4 inches in diameter, blown with two 10 inch tuyeres and 7 inches column of blast, and melting about 9 tons of iron per hour: a cupola 2 feet 9 inches diameter with two 6 inch tuyeres and 7 inches column of blast he had found would bring down 6 tons of iron per hour. In the new cupola the blast on entering became heated up at once to a high temperature by passing through a heap of red-hot fuel; the oxygen was thus

mostly combined with carbon before meeting the melted iron dropping into the hearth, and the level of greatest heat was also brought down nearer to the hearth. The iron was therefore less liable to be burnt, having less height to fall through the entering blast; and the large size of the hearth in proportion to the rest of the cupola allowed of a large quantity of melted metal being kept hot ready for tapping. The cupola appeared likely he thought to stand very well in regular work, and it certainly gave promise of being decidedly economical.

Mr. J. Fernie thought the height of the new cupola was hardly so great as might be desirable for the greatest economy; and in the case of other cupolas any alterations made in this respect had been in the direction of increasing the height rather than the contrary. The economy of fuel obtained with the new cupola appeared to be about the same as in the cupola the first form of which he had described at a previous meeting (see Proceedings Inst. M. E. 1856, page 49). In that cupola the blast was admitted through a large number of holes arranged in a belt all round the cupola, instead of the ordinary two large tuyere holes; and the consumption of coke was brought down to only $1\frac{1}{4}$ cwt. per ton of iron melted, when the cupola was kept going in continuous work. Moreover with the number of smaller holes the blast was more diffused, and the iron was less burnt in consequence.

Mr. C. C. Walker thought the form of a cupola had a great deal to do with its economy. He had lately been making some experiments upon this question with an ordinary cupola, 6 ft. 6 ins. high from the hearth to the charging hole, and melting down about 14 or 15 cwts. of iron per hour, with two tuyeres, one on each side, blowing in the ordinary way. The consumption of fuel was rather less than 3 cwts. of Durham coke per ton of iron melted, and a considerable quantity of flame came out at the top. The charging hole was then raised 18 inches, and it was found in a trial of three or four weeks duration that the consumption was thereby reduced to $2\frac{3}{4}$ or $2\frac{1}{2}$ cwts. of coke per ton, while the flame previously escaping at the top had nearly ceased. He had further made trial of the plan which had been referred to, of introducing the blast by means of two

rings of holes round the cupola, eight holes in all, instead of a single pair of tuyere holes; and at the same time the inside of the cupola was altered to a shape more like that of a blast furnace, by narrowing it in diameter for about 15 inches height, the narrowing commencing at about 15 inches from the floor or hearth. The result then obtained in a trial of several weeks was certainly a great economy of fuel, the consumption being only $1\frac{1}{2}$ cwts. of coke for melting down 1 ton of iron, and the flame at the top ceased; and he understood that, in another trial of the same plan of blowing, the consumption had been found to be even as low as $1\frac{1}{4}$ cwts. of coke per ton of iron, though he doubted whether the heat of the melted iron was sufficient for ordinary castings with so low a consumption of coke. This experiment did not indeed determine whether the economy thus obtained was due to the mode of blowing, or to the narrower bottom of the cupola; but he was led to believe that the latter was the main source of advantage, because he had been informed that where the increased number of blast holes had been tried, independent of any alteration in the shape of the cupola, no advantage had been experienced in economy; and moreover, in the case of the Bessemer process, the sets of numerous small holes originally employed for introducing the blast had now been replaced by two single holes only in each converting vessel, which were found equally effective for blowing the metal. It appeared therefore that the narrowing of the bottom of the cupola resulted in as great an economy of fuel as that obtained with the new cupola described in the paper, and he did not see that there were any other important advantages in the new cupola; he asked what description of coke had been used in it, and also what arrangement was made for letting the slag run off from the surface of the melted metal in the hearth. With regard to the air passages shown in the drawings for admitting the blast in the new cupola, he thought it was questionable whether much advantage would really be gained from that arrangement in heating the blast before it reached the fuel, because the air passed with such rapidity that there was hardly time for it to become much heated in so short a distance.

Mr. Eichhorn thought that although the blast entered the cupola at so great a velocity, it must become highly heated in the air chambers, because the outside of the cupola even at those places was so hot that it was impossible to bear the hand upon it; which would hardly be the case if the blast remained cold. The coke which he had used in the cupola in London was the ordinary Newcastle coke; and the slag was as usual allowed to run off through a slag hole in the door containing the tapping hole, as shown in the drawing. In respect to the question of economy, there was an important reduction in the waste of iron in the new cupola, the loss being only 3·4 per cent. in melting pig iron such as Calder No. 1, and only 2·2 per cent. when mixed with three fourths of railway-chair scrap; whereas the average waste in ordinary cupolas was found to be 5 per cent. with the same materials.

Mr. C. C. Walker observed that the waste of iron depended partly upon its quality, as well as upon the construction of the cupola in which it was melted; and in the case of the Cleveland iron the waste was so considerable that he understood at some ironworks its use had been abandoned, and a more expensive but less wasteful description of iron adopted instead, though he could not say that was his own experience.

Mr. C. W. Siemens thought that as regarded waste of iron the construction of the new cupola was decidedly advantageous; because not only was the zone of greatest heat brought down nearer to the hearth, whereby the iron dropping into the hearth was less exposed to the blast, but also the melted metal in the hearth had a large part of its surface covered by the heap of fuel lying upon it, which effectually protected it from oxidation.

The Chairman enquired how long the new cupola had been in use, and to what extent it was now employed; and what was the average daily quantity of iron melted.

Mr. Eichhorn replied that the cupola had now been at work for six months at Messrs. Whitley and Son's foundry in London, and for about eighteen months in Germany, where it was extensively in use at many ironworks. The quantity of iron melted in the one in London had been from $1\frac{1}{2}$ to 3 tons per day, and the average

might safely be taken at 2 tons per day during the whole period; the same results were also obtained with the cupolas at work in Germany.

Mr. T. Claridge observed that in some experiments which he had made with an ordinary cupola he had found great economy was occasioned by increasing the height. The original height had been only 7 feet from the tapping hole up to the charging hole, and at that time the materials were always at a red heat at the charging hole. But when the height was increased to 14 feet there was only a black heat at the charging hole, and the heat passing up from the lower portion of the cupola was usefully employed in heating the descending materials above. In this case the diameter of the cupola was 2 feet, giving the proportion of 7 to 1 between the height and the diameter; and he considered the height from the tapping hole to the charging hole should always bear a certain proportion to the diameter, and he believed the proportion of 7 to 1 was the most satisfactory for economy of fuel. With this proportion he had found that the previous consumption of 3 cwts. of coke per ton of iron had been reduced to only $1\frac{1}{4}$ cwts. in the higher cupola; and the iron brought down was very much harder in quality than had previously been the case with the greater consumption of coke.

The Chairman remarked that a constant proportion of 7 to 1 between the height and the diameter of a cupola would require the larger cupolas to be much higher than was generally the case at present; a cupola of 3 feet diameter would then have to be 21 feet high up to the charging hole.

Mr. T. Claridge said that 3 feet diameter was a very large size for a cupola; but if that size were adopted he considered the same proportion should still be adhered to, and the height should certainly not be less than 21 feet; if it were less, there would be a corresponding diminution of economy, owing to the greater quantity of heat escaping to waste at the top. The objection to a great height of cupola was the increased time and labour of raising the materials for charging; and mechanical arrangements would be required for the purpose wherever the height was considerable.

With regard to the plan which had been referred to of blowing a cupola through a number of small holes round its circumference, he

believed this was not intended to be used in substitution for the two large tuyeres ordinarily employed, but in conjunction with them, the smaller holes being situated about 3 feet height above the tuyeres; in first starting the cupola to work the two tuyeres were used alone for a short time, until the iron began to run down, and then the blast was admitted through the upper holes. The advantage of that plan appeared to him to be that a greater volume of blast was thereby blown into the cupola, and distributed over a greater area, in consequence of which the iron was brought down with greater rapidity.

The Chairman enquired in what manner the quantity of blast supplied to the new cupola had been ascertained; it appeared from the statement in the paper that the supply of blast was as much as 100,000 cubic feet per hour per ton of iron melted.

Mr. Eichhorn replied that the quantity of blast had been estimated by calculation from the pressure and the area of the blast main, by means of the ordinary formula $Q = C \times A \times V$, Q being the quantity of blast supplied per second in cubic feet, A the area of the blast orifice in square feet, V the velocity of the issuing blast in feet per second, and C a coefficient for the loss by friction in the blast main. The value of this coefficient, deduced from experiments, was given by Wiesbach as 0·7; and putting h to represent the height in inches of the column of water indicating the pressure of the blast in the main, and taking the specific gravity of atmospheric air as $\frac{1}{800}$ compared with water, the above formula became $Q = 0{\cdot}7 \times A \times 8 \surd (800 \times h \div 12)$, expressing the velocity in terms of the height in inches; or

$$Q = 45{\cdot}7 \times A \times \surd h$$

that is, the quantity of blast supplied in cubic feet per second was the product of the area of blast orifice in square feet, multiplied by the coefficient 45·7 and by the square root of the number of inches height of water column indicating the pressure of blast in the main. The pressure of blast which had been found best to be employed in the cupola was 4 to 5 inches column of water. If the supply of blast to ordinary cupolas were calculated in the same way, it would be found to be quite as great as in the new cupola. In the instance

of the cupola now at work in London, the same blowing fan was used as for the ordinary cupola previously employed, and the area of the furnace was now reduced in the proportion of 7 to 3 for melting the same quantity of metal.

The CHAIRMAN proposed a vote of thanks to Mr. Eichhorn for his paper, which was passed.

The Meeting then terminated.

Fig. 1. *Section of Spencer Cartridge. Rim-Fire.*

Fig. 2. *Transverse Section at* XX

Fig. 3. *Section of Boxer Cartridge. Central-Fire.*

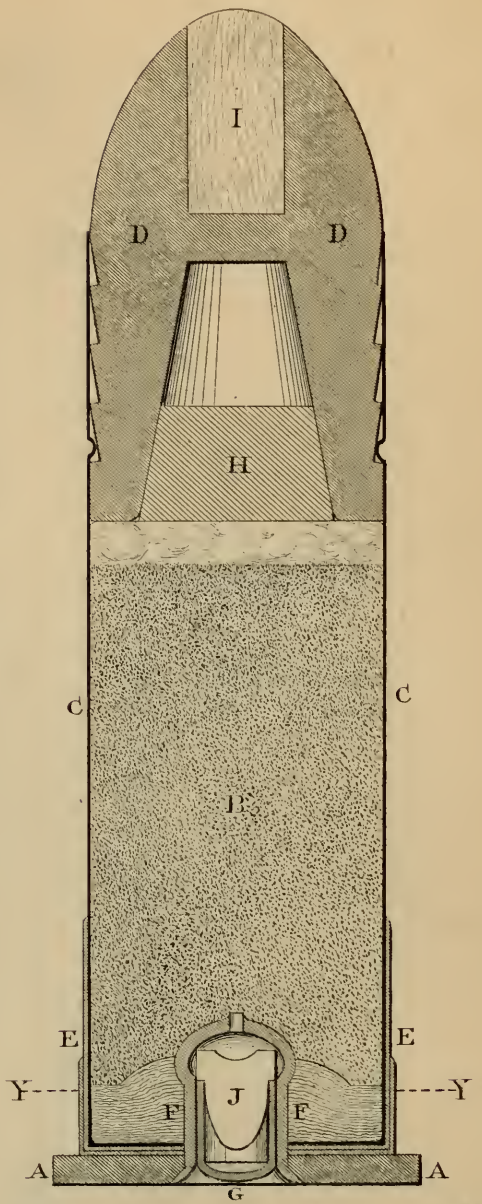
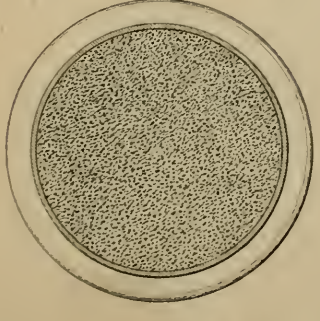
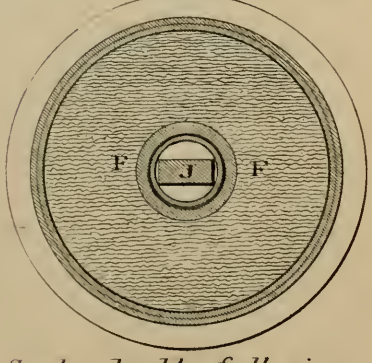


Fig. 4. *Transverse Section at* YY.





(Proceedings Inst. M. E. 1868.) *Scale double full size.*

CARTRIDGE MACHINERY.

Fig. 5. *Bullet-Making Machine.* *First operation.*

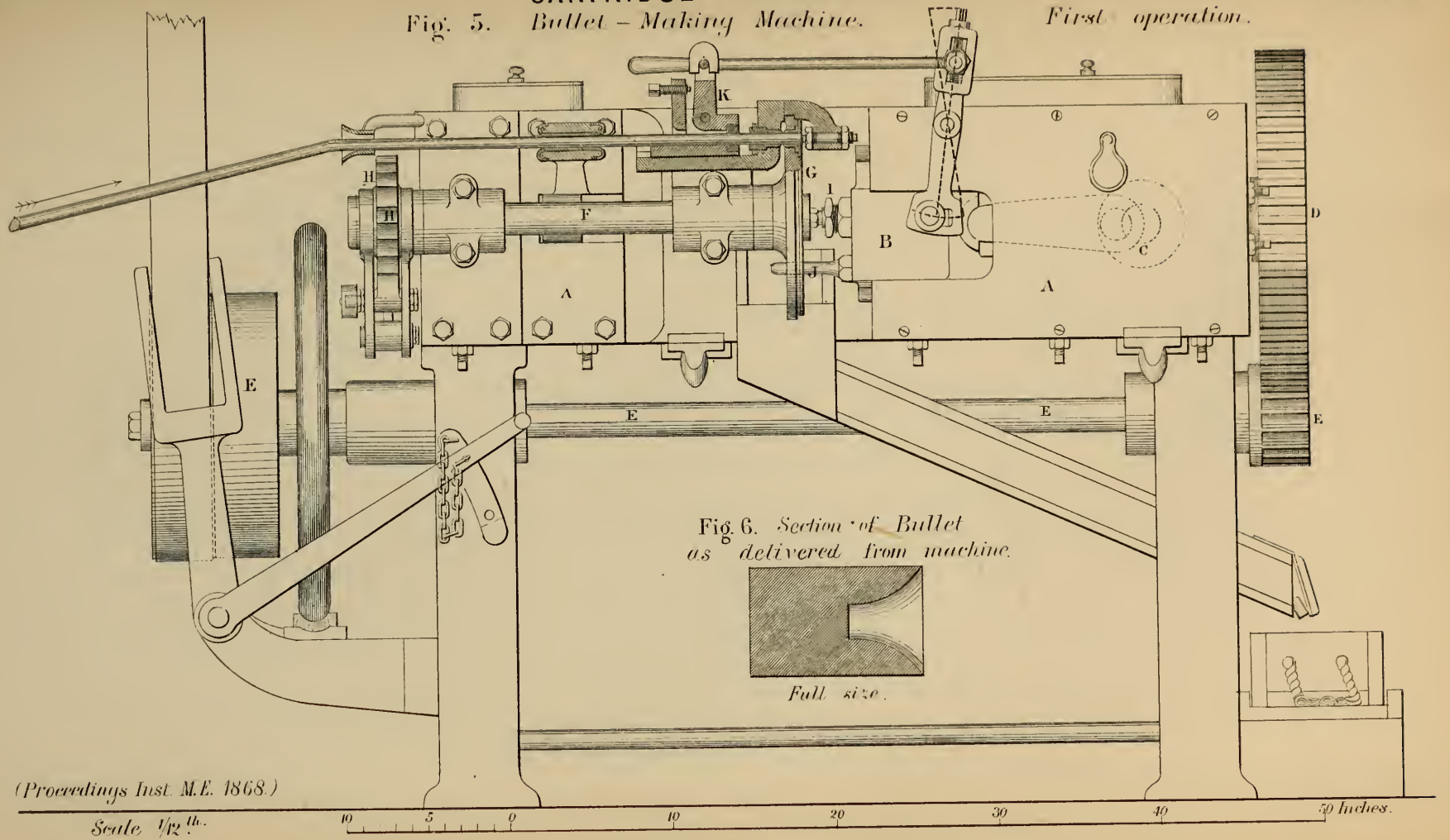


Fig. 6. *Section of Bullet as delivered from machine.*

Full size.

(Proceedings Inst. M.E. 1868.)

Scale 1/12th.

10 5 0 10 20 30 40 50 Inches.

CARTRIDGE MACHINERY.

Fig. 7. *Bullet-Making Machine.* *Second operation.*

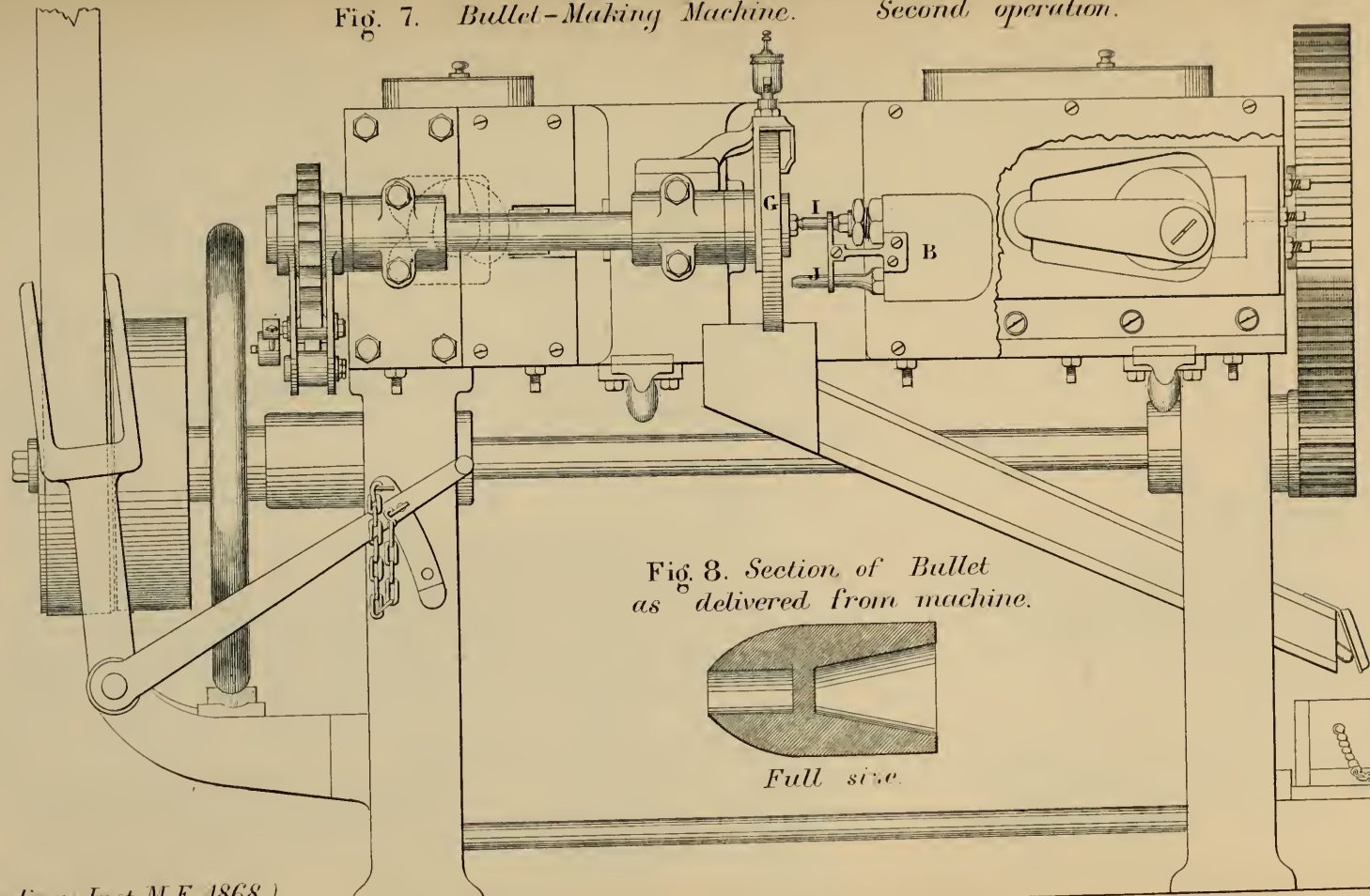


Fig. 8. *Section of Bullet as delivered from machine.*

Full size.

(Proceedings Inst. M.E. 1868.)

Scale 1/12 th.

10 5 0 10 20 30 40 50 Inches.

CARTRIDGE MACHINERY.

Bullet Making Machine. Second operation.

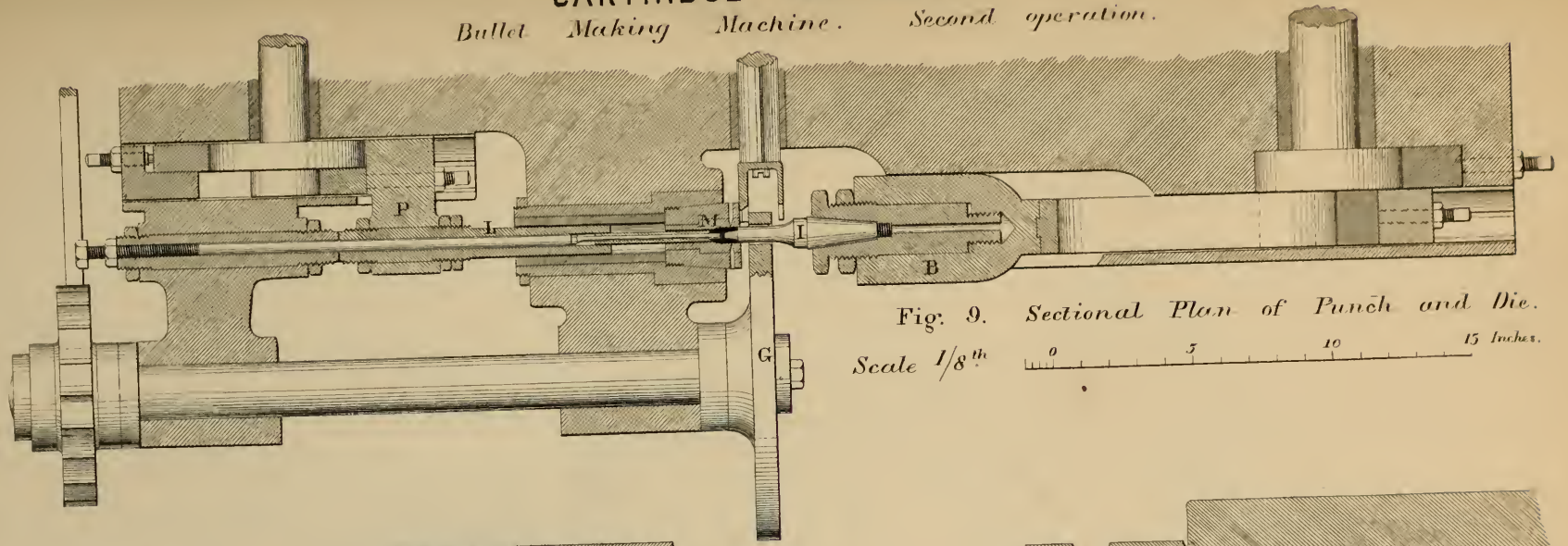
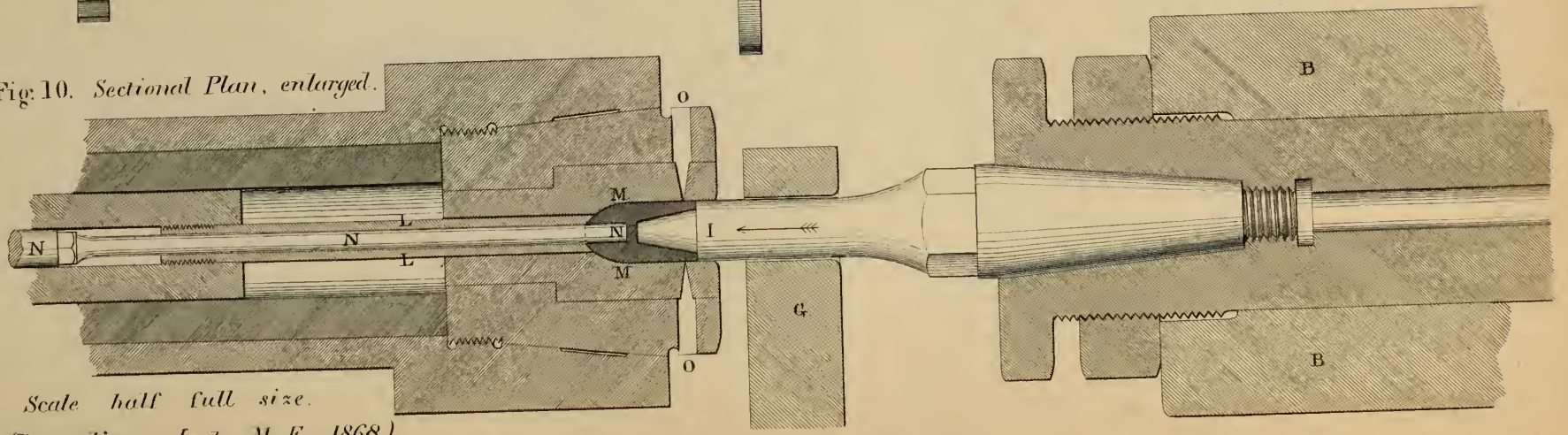


Fig. 9. *Sectional Plan of Punch and Die.*

Scale 1/8th 0 5 10 15 Inches.

Fig. 10. *Sectional Plan, enlarged.*



Scale half full size.

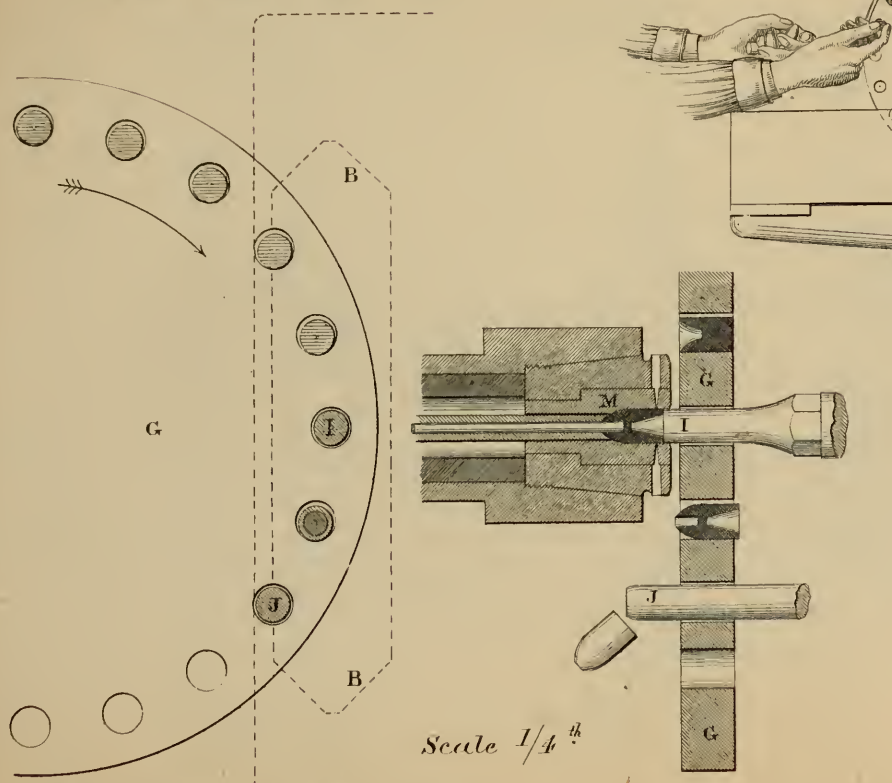
(Proceedings Inst. M. E. 1868.)

CARTRIDGE MACHINERY.

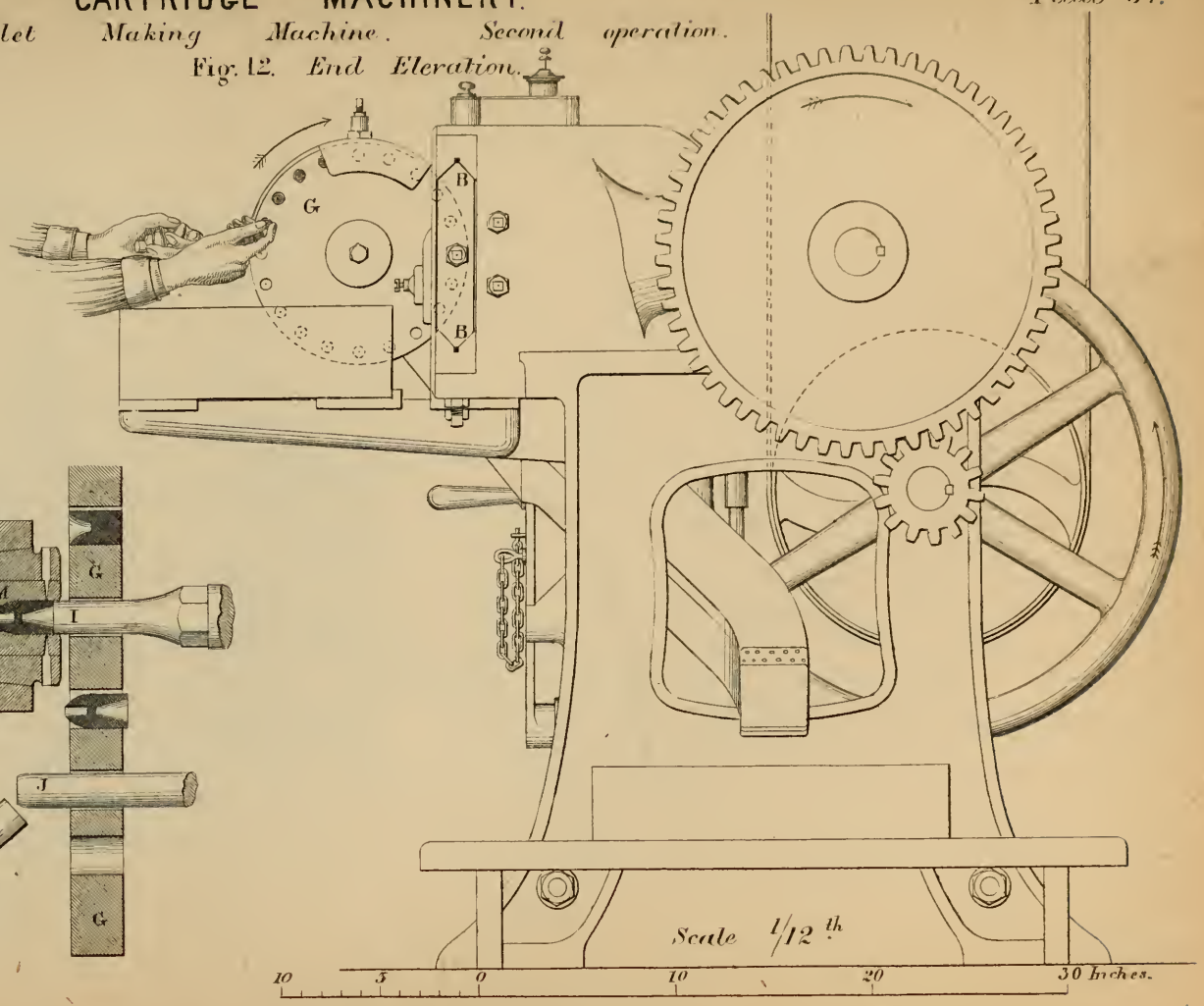
Bullet Making Machine. Second operation.

Fig. 12. *End Elevation.*

Fig. 11. *Feed Plate, with Punch and Die.*



Scale 1/4 th.



(Proceedings Inst. M. E. 1868)

Canneluring Machine.

Fig. 13.
Plan.

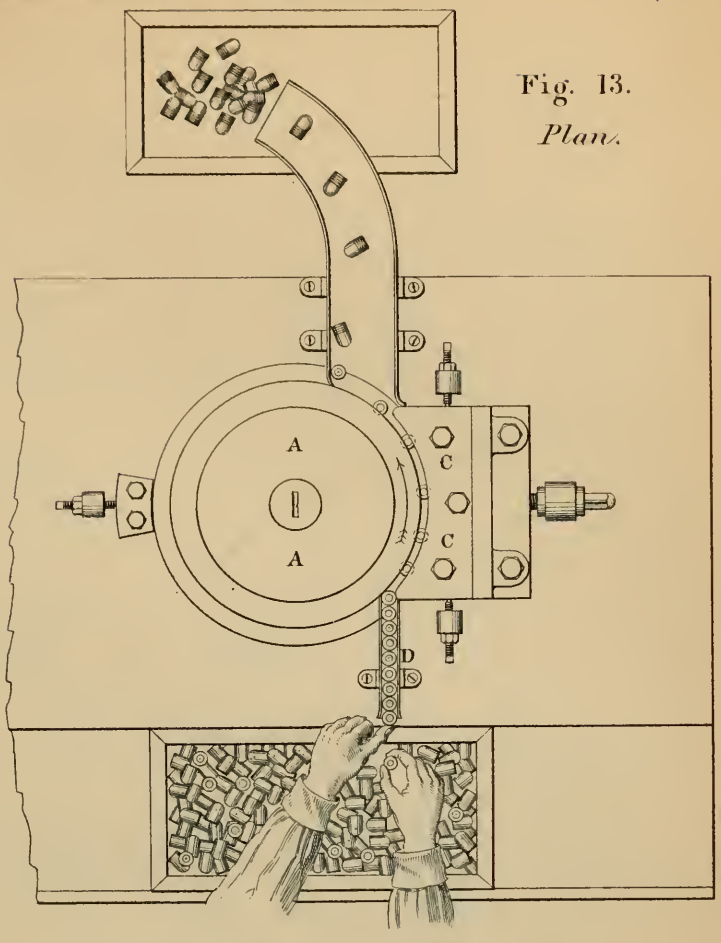
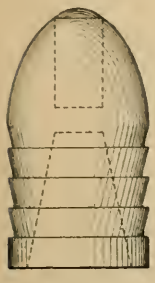
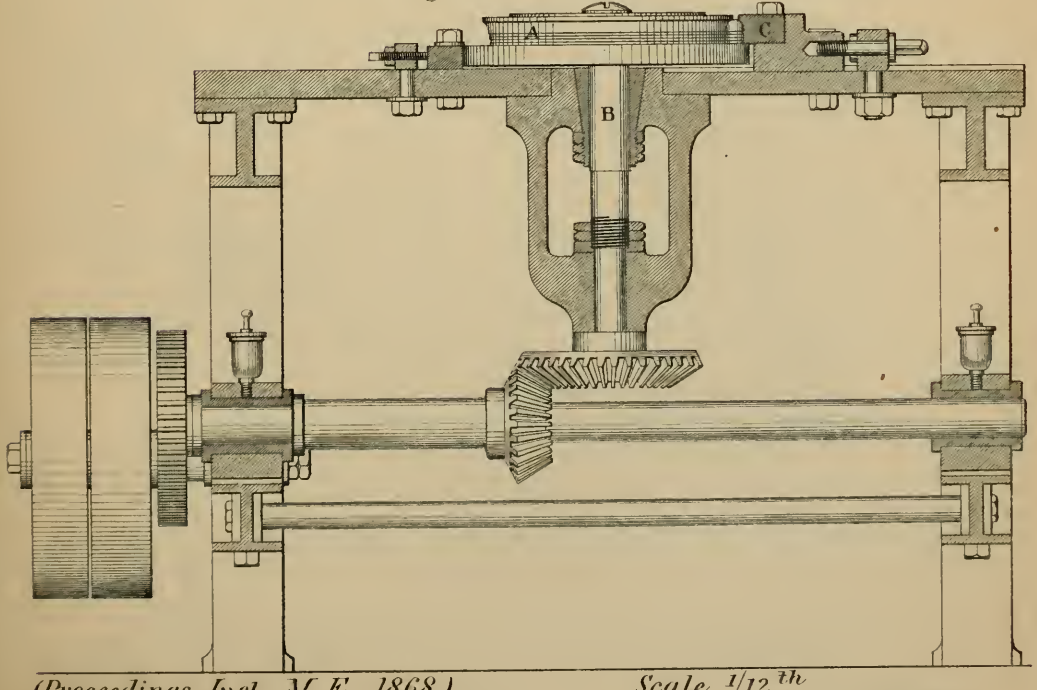


Fig. 15. *Bullet after passing thro' machine.*



Full size.

Fig. 14. *Vertical Section.*



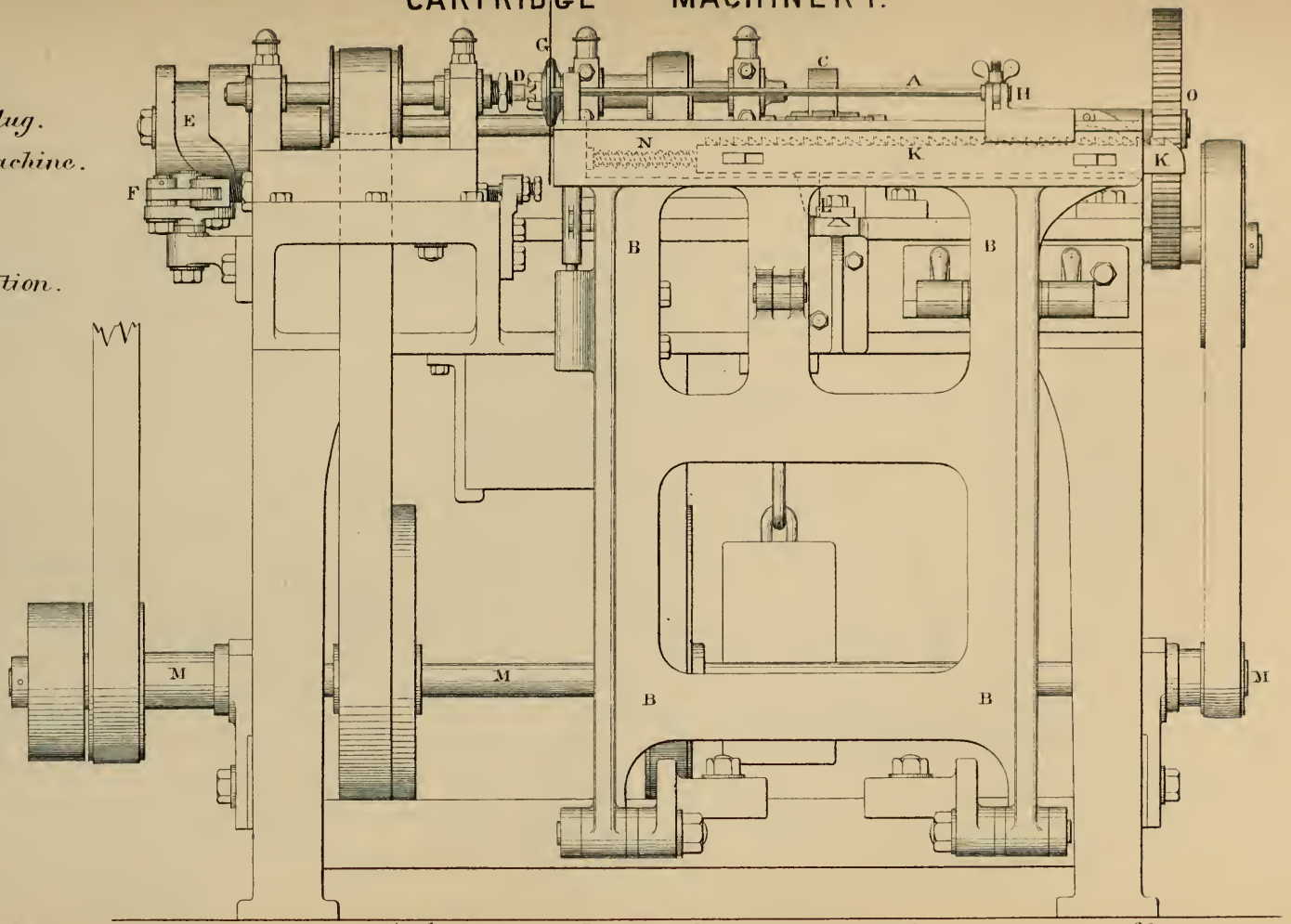
(Proceedings Inst. M.E. 1868.) *Scale 1/12th.*

10 5 0 10 20 30 Inches.

CARTRIDGE MACHINERY.

Wood Plug. Making Machine.

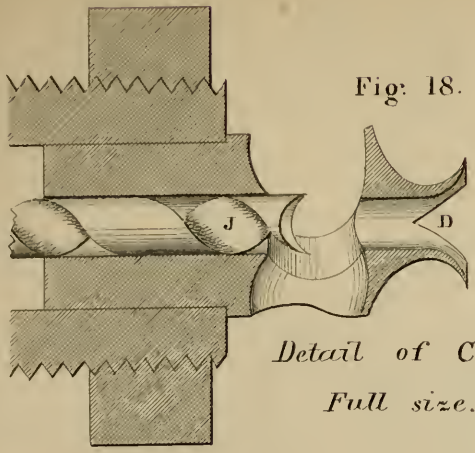
Fig: 16.
Front Elevation.



(Proceedings Inst. M.E. 1868.) *Scale 1/10th* 10 5 0 10 20 30 Inches.

Wood Plug Making Machine.

Fig: 18.



Detail of Cutter.
Full size.

Fig: 19.

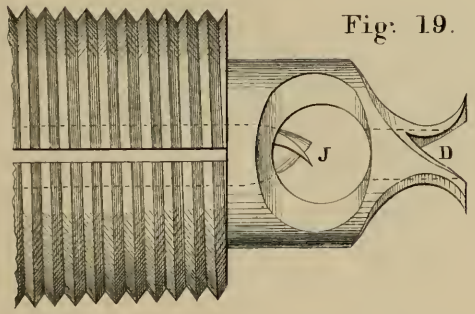
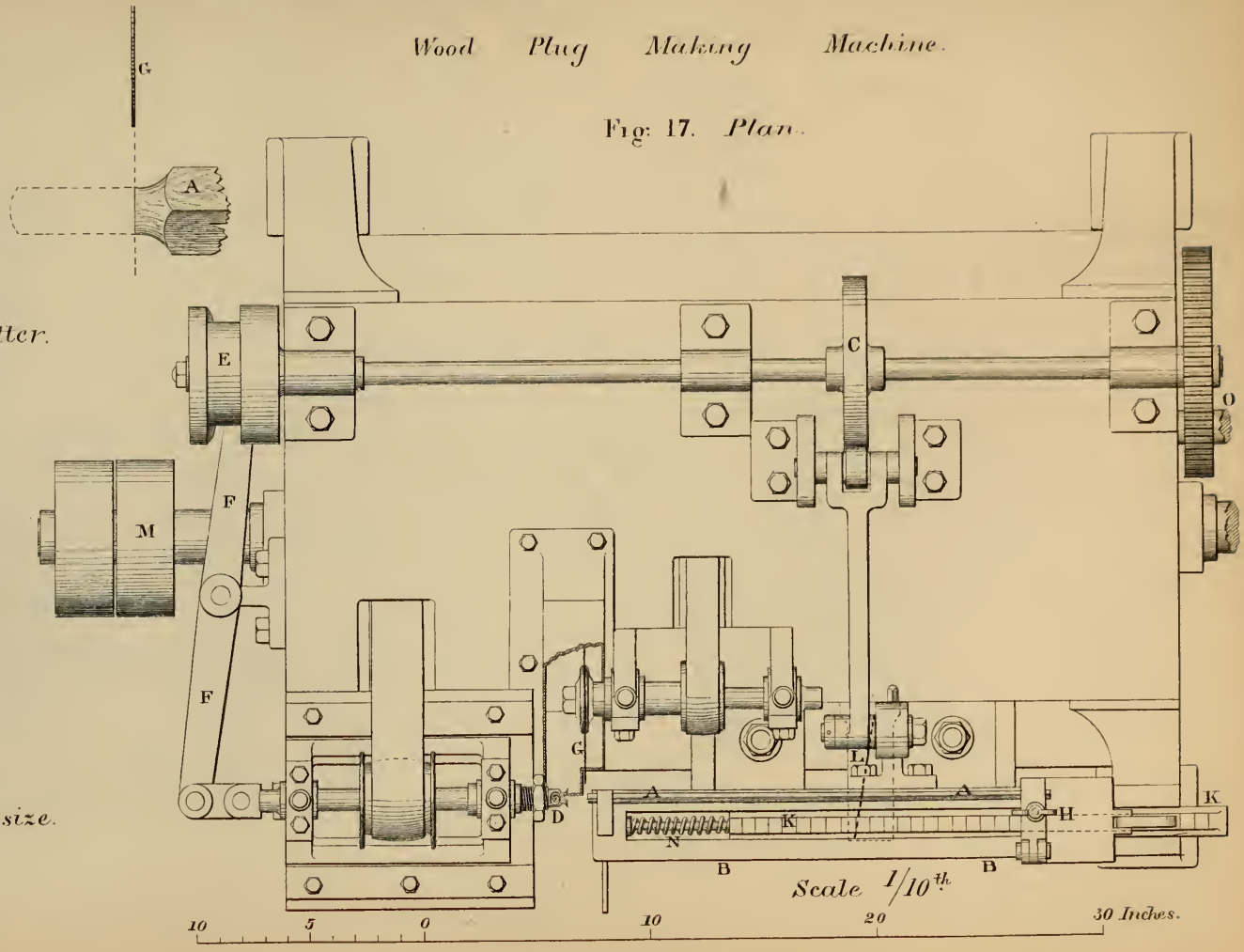


Fig: 20. *Wood Plug. Full size.*

(Proceedings Inst. M. E. 1868)

Fig: 17. *Plan.*

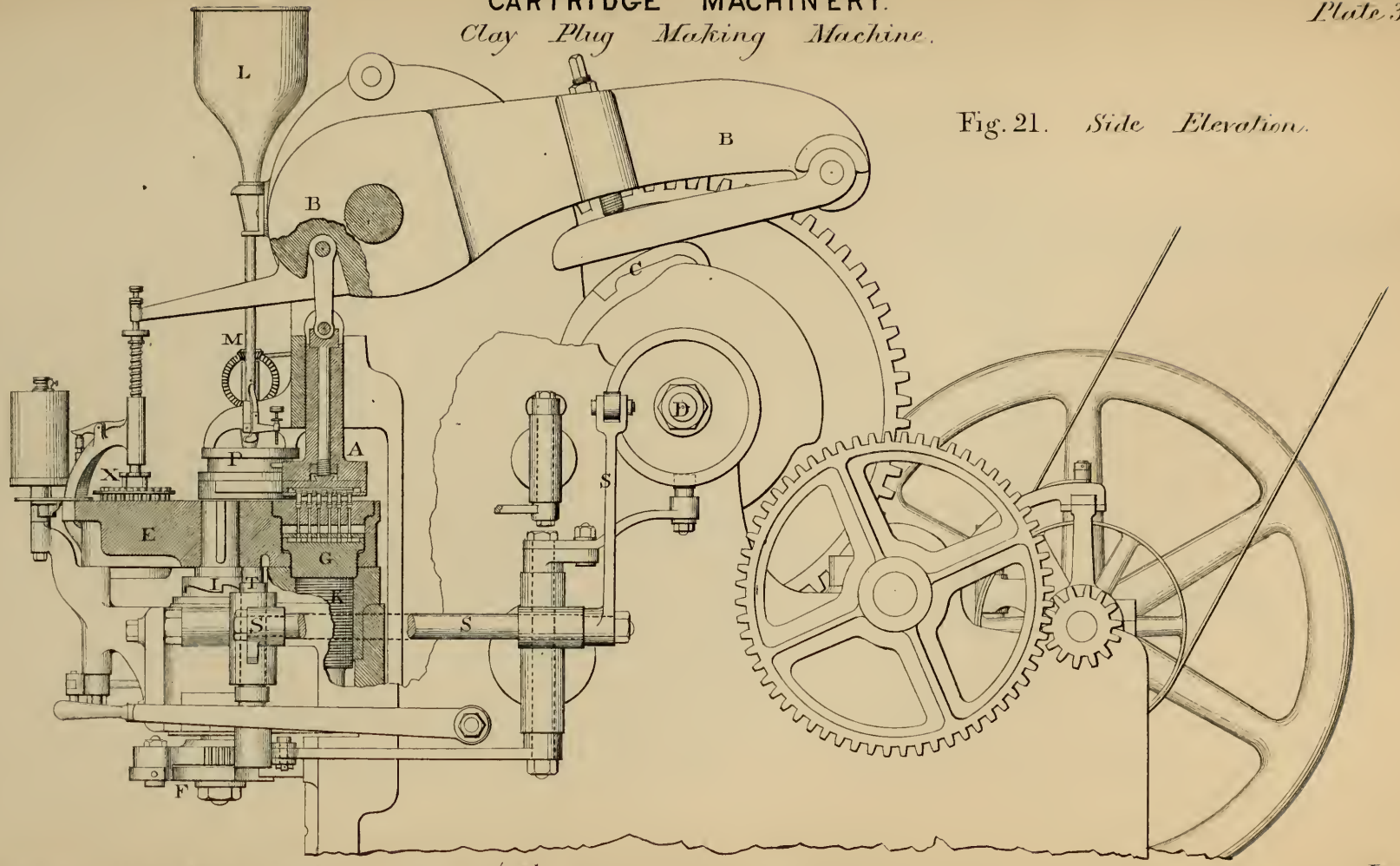


CARTRIDGE MACHINERY.

Clay Plug Making Machine.

Plate 38.

Fig. 21. *Side Elevation.*



(Proceedings Inst. M. E. 1868.) *Scale* 1/16th

10 5 0 10 20 30 40 50 Inches.

CARTRIDGE MACHINERY.

Clay Plug Making Machine.

Fig. 23. *Plan of Moulding Table.*

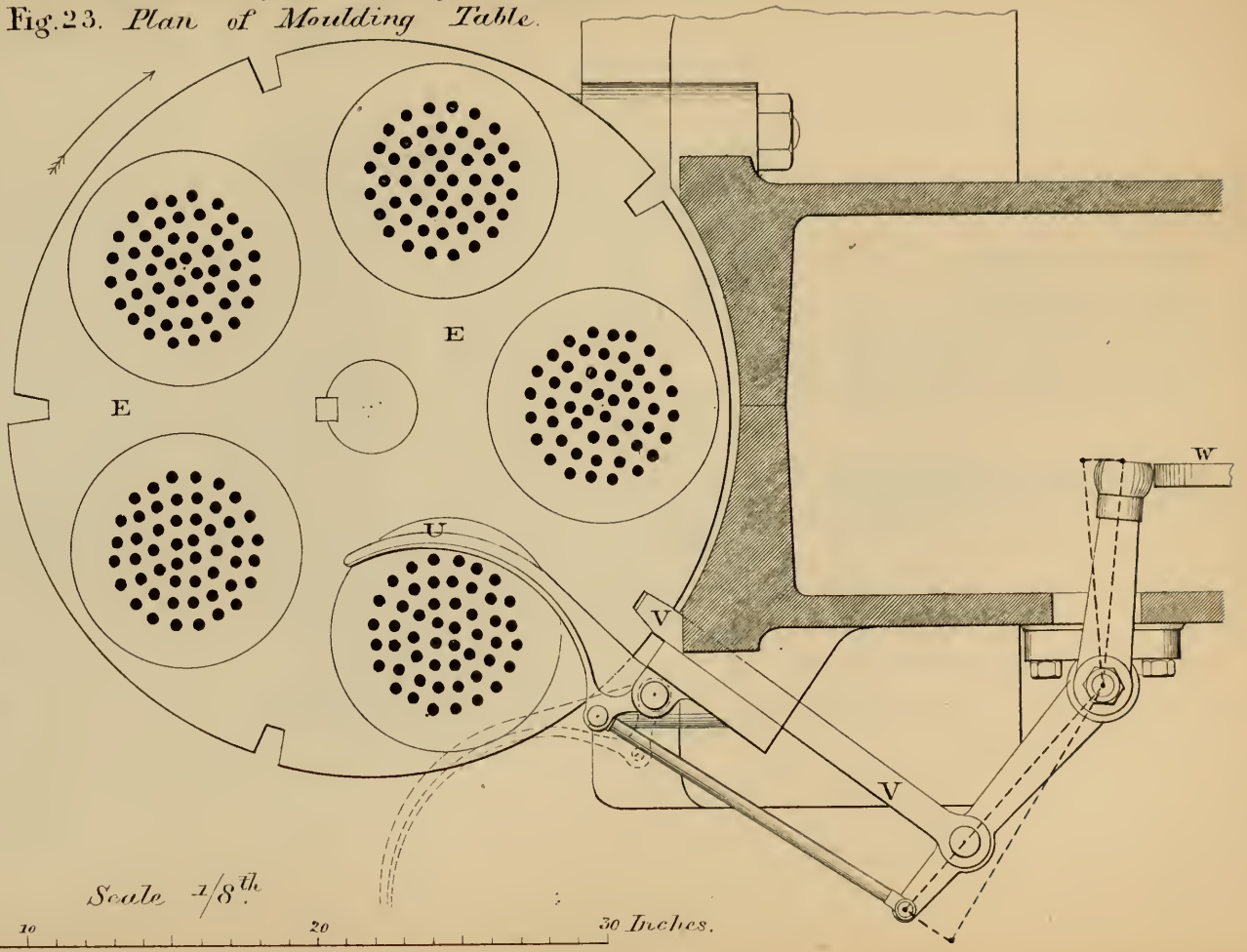
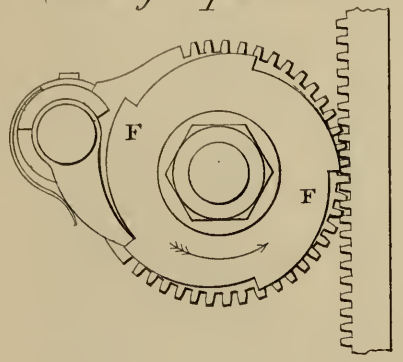


Fig. 22.

Plan of Ratchet Wheel turning the Moulding Table, (looking upwards.)



(Proceedings Inst. M. E. 1868.)

Scale 1/8th

0 10 20 30 Inches.

Clay Plug Making Machine.

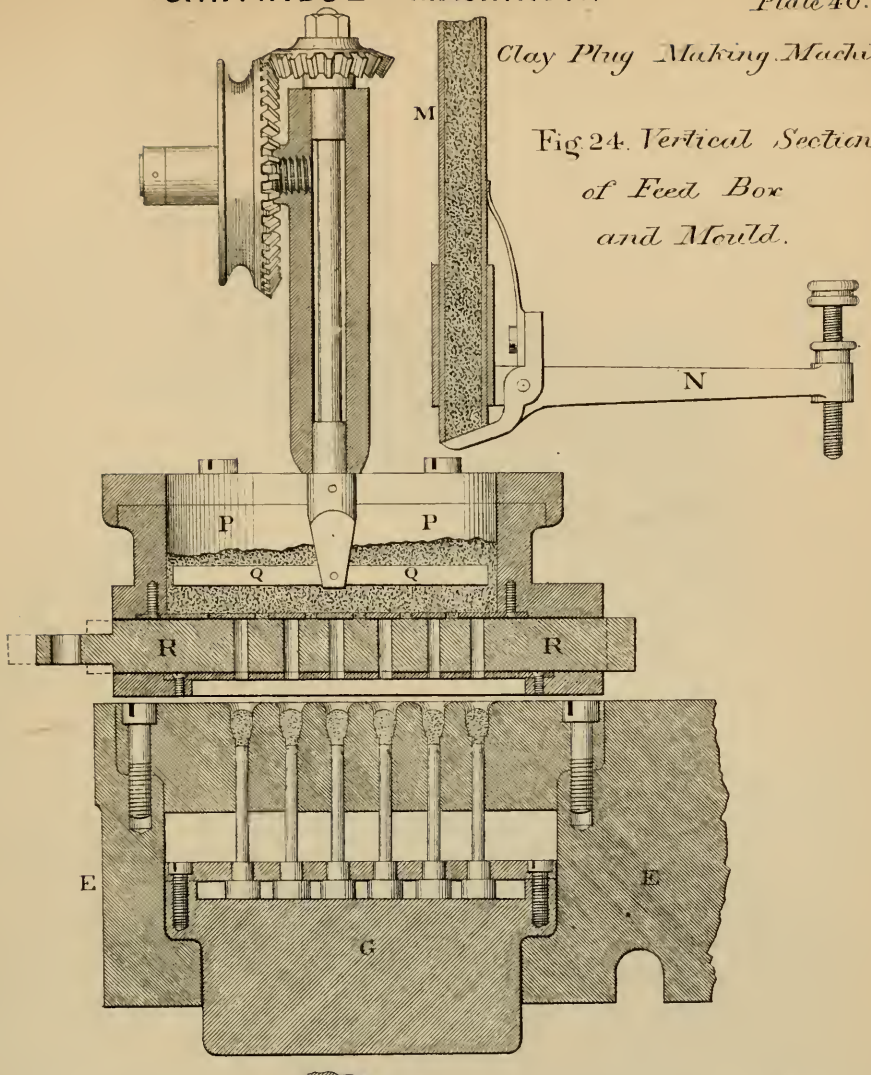


Fig. 24. Vertical Section of Feed Box and Mould.

Fig. 25. Vertical Section of Pressing Slide and Mould.

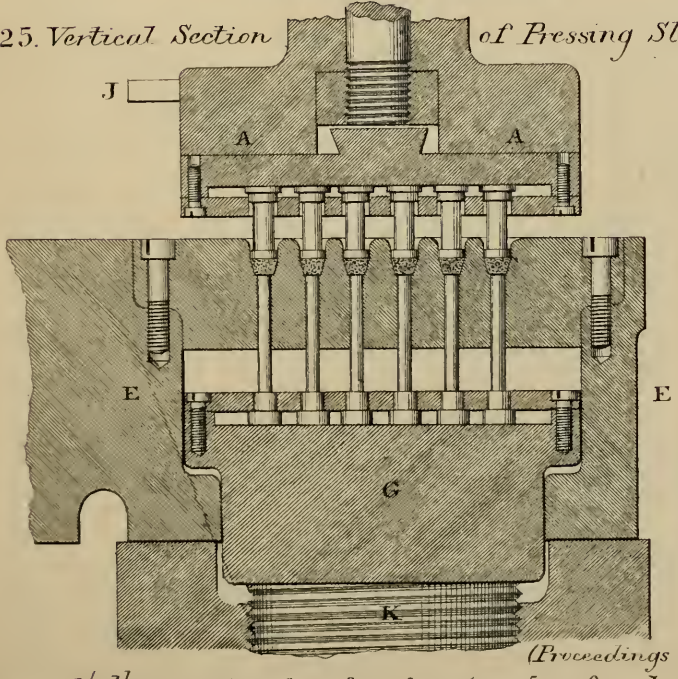
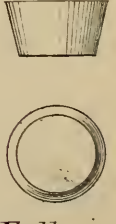


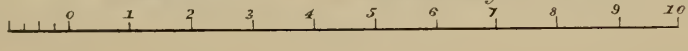
Fig. 26.
Clay Plug.



Full size.

(Proceedings Inst. M.E. 1868.)

Scale 1/4th.



Machine for Warming and Gauging the Bullet, and Pressing in the Clay Plug.

Fig. 27. *Plan.*

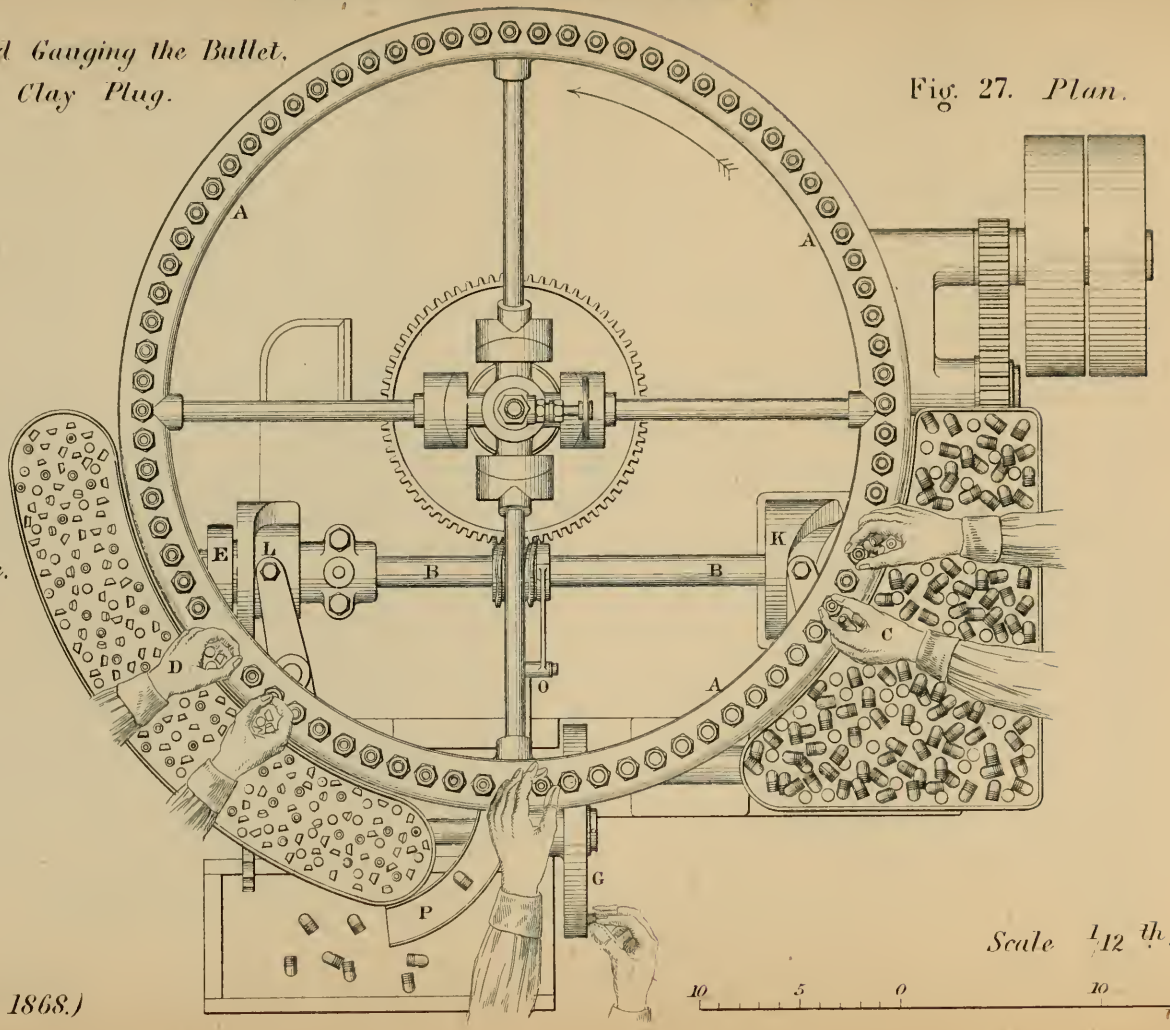
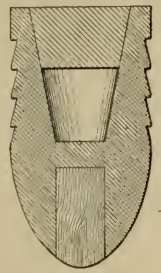


Fig. 28.
Section of Bullet as delivered from machine.



Full size.

Scale $\frac{1}{12}$ *th.*

10 5 0 10 20 Inches.

(Proceedings Inst. M. E. 1868.)

Machine for Warming and Gauging the Bullet, and Pressing in the Clay Plug.

Fig. 29. *End Elevation.*

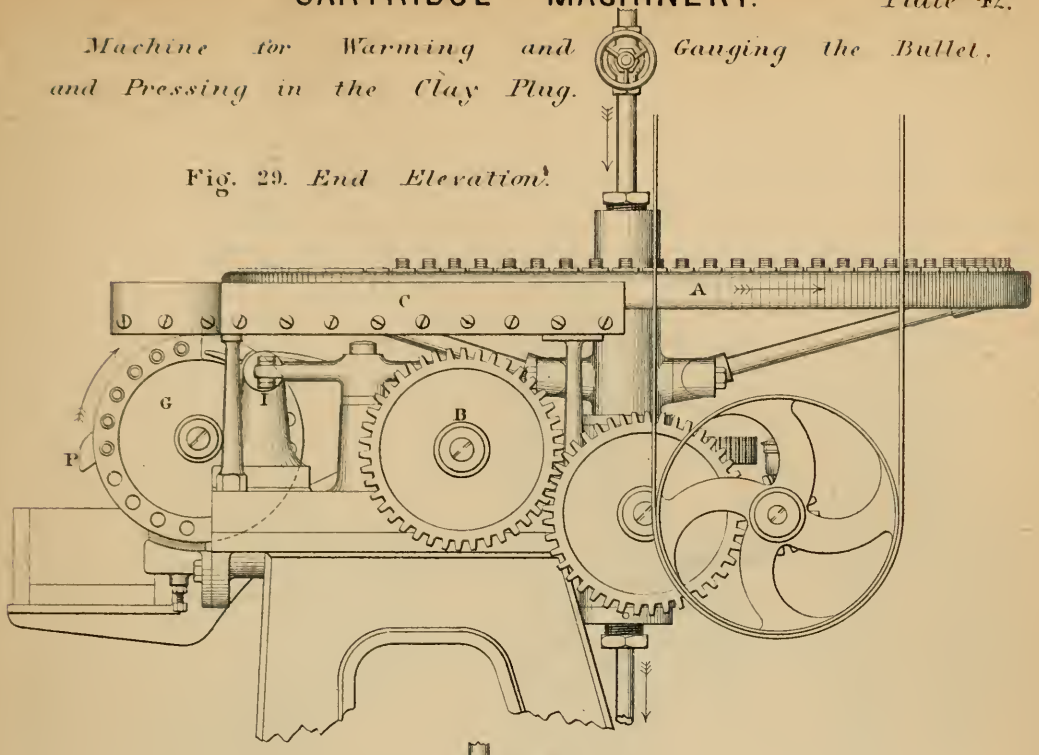
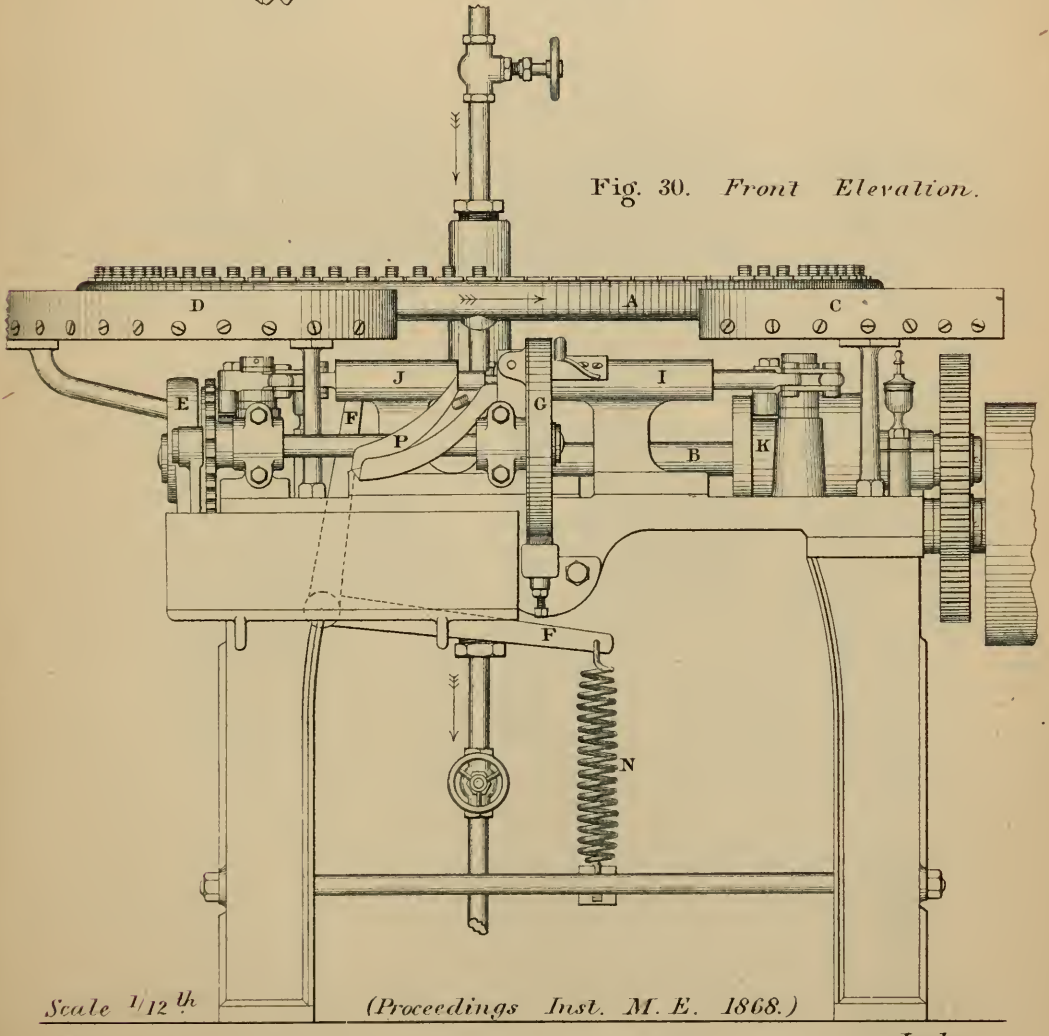


Fig. 30. *Front Elevation.*



Scale 1/12 th

(Proceedings Inst. M. E. 1868.)

10 5 0 10 20 30 Inches.

Pressing in the Clay Plug, and Gauging the Bullet.

Fig. 31. *Bullet in the Feed Plate.*

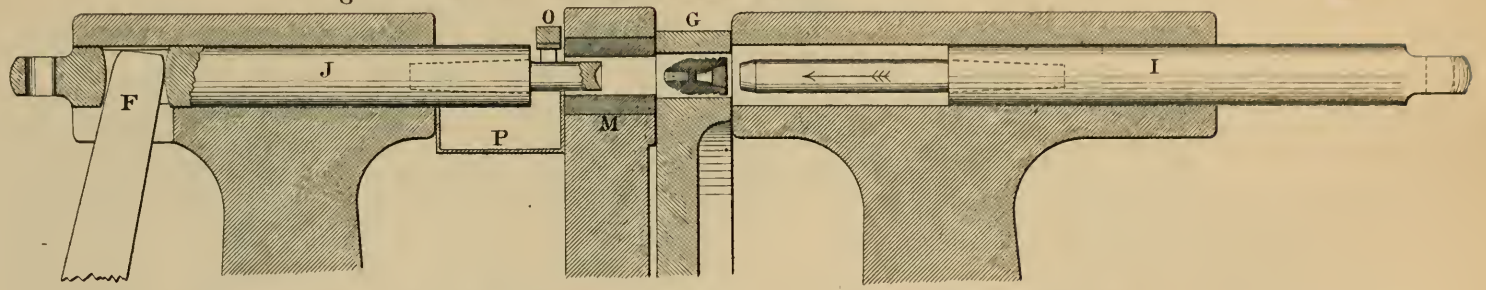


Fig. 32. *Bullet in the Gauge, and Clay Plug pressed in.*

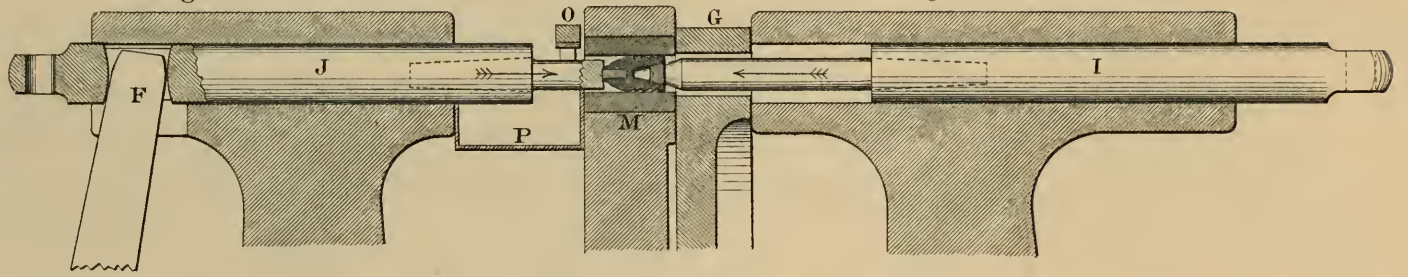
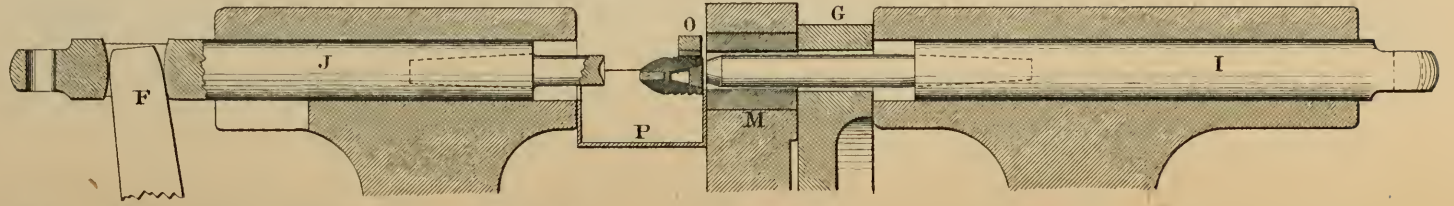
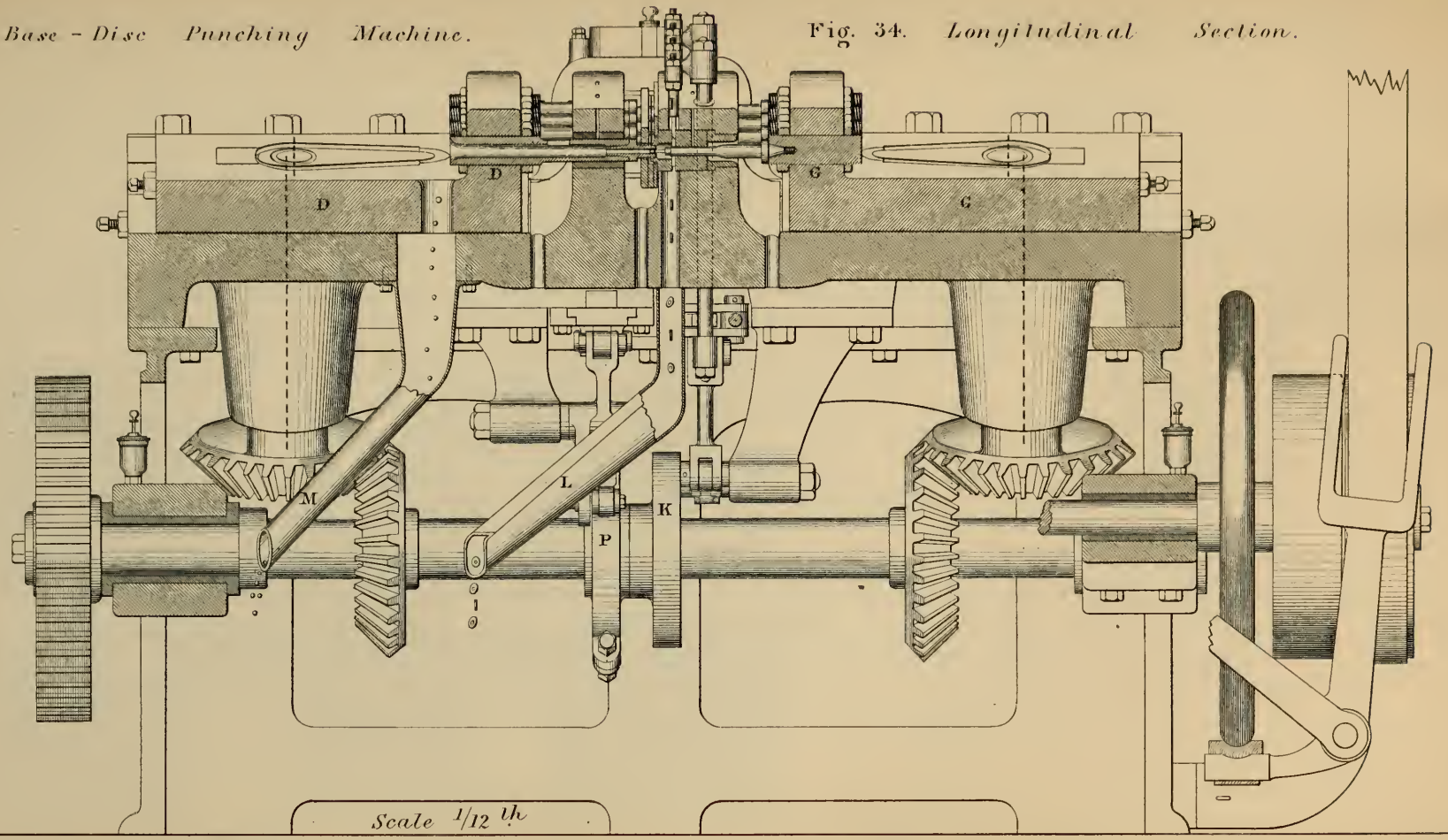


Fig. 33. *Bullet discharged from Gauge.*



(Proceedings Inst. M. E. 1868.) *Scale 1/4 th*

Base-Disc Punching Machine. Fig. 34. *Longitudinal Section.*

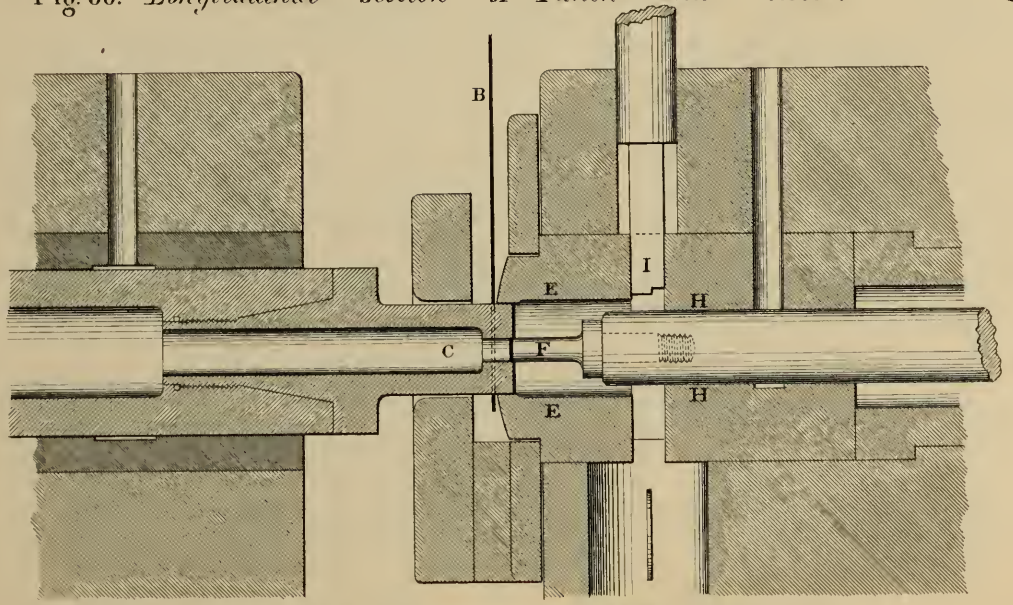


(Proceedings Inst. M.E. 1868.)

Base - Disc Punching Machine.

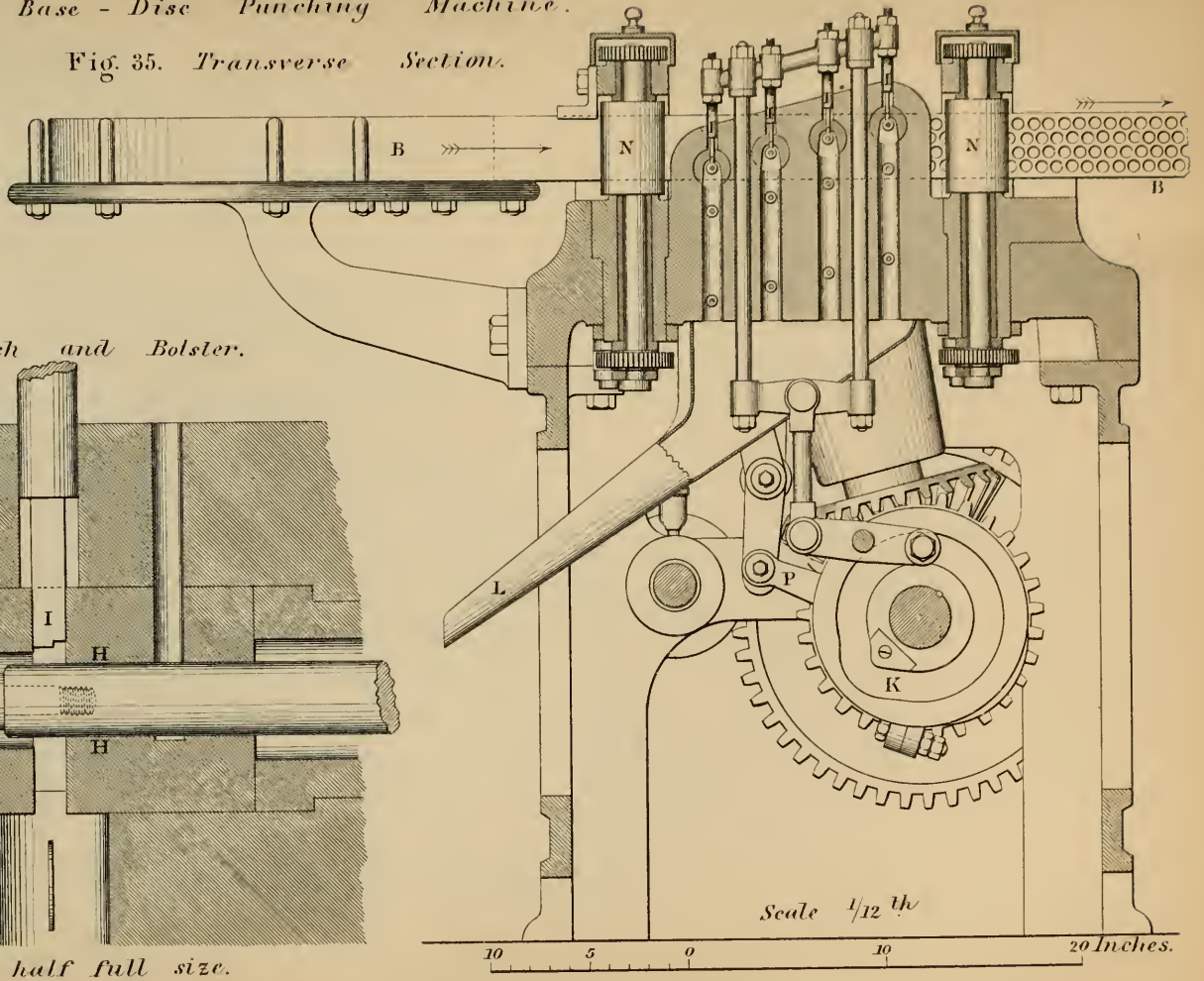
Fig. 37. *Base Disc, full size.*

Fig. 36. *Longitudinal Section of Punch and Bolster.*



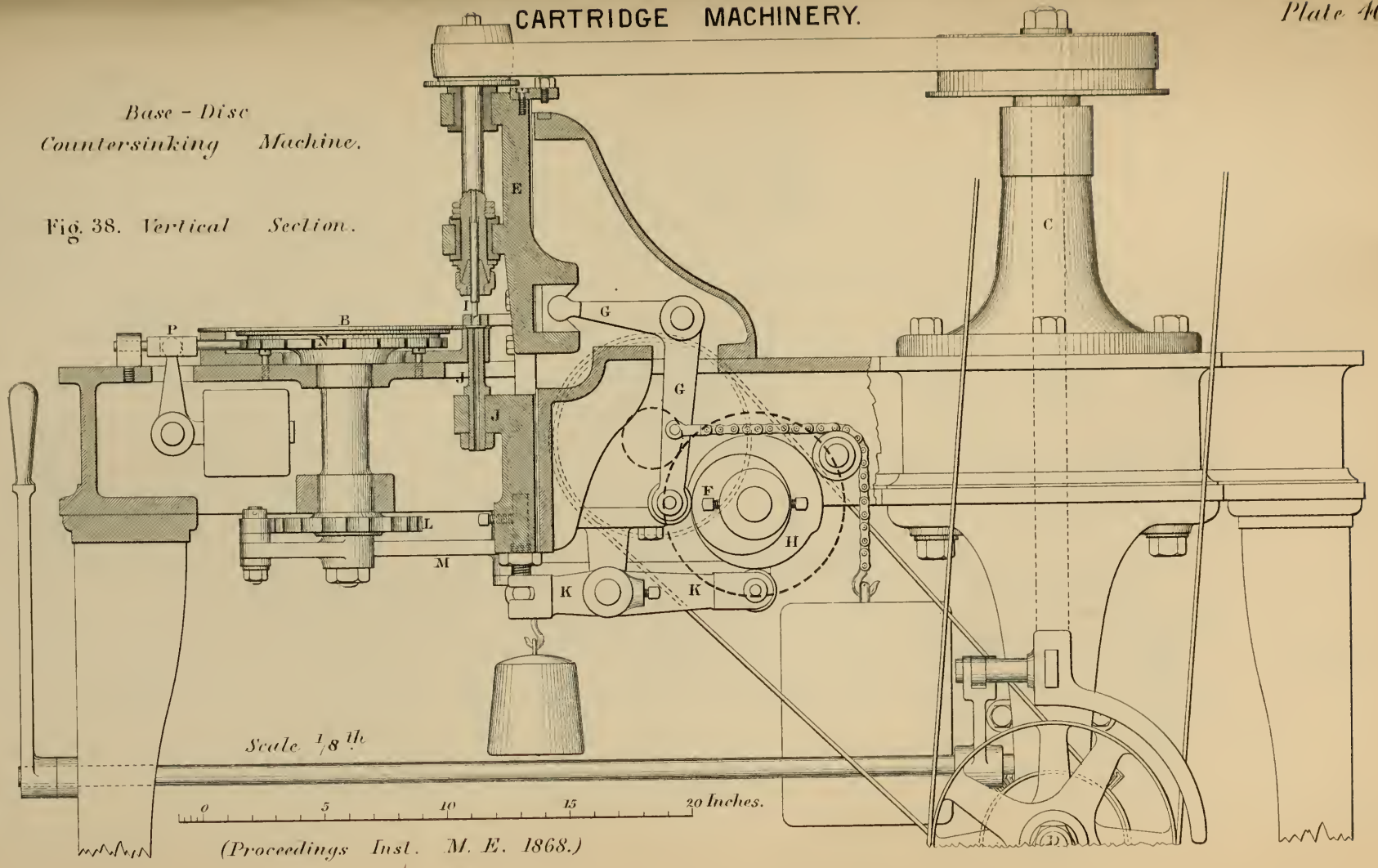
(Proceedings Inst. M. E. 1868.) *Scale half full size.*

Fig. 35. *Transverse Section.*



Base - Disc Countersinking Machine.

Fig. 38. *Vertical Section.*



(Proceedings Inst. M. E. 1868.)

Base-Disc Countersinking Machine.

Fig. 39. *Plan.*

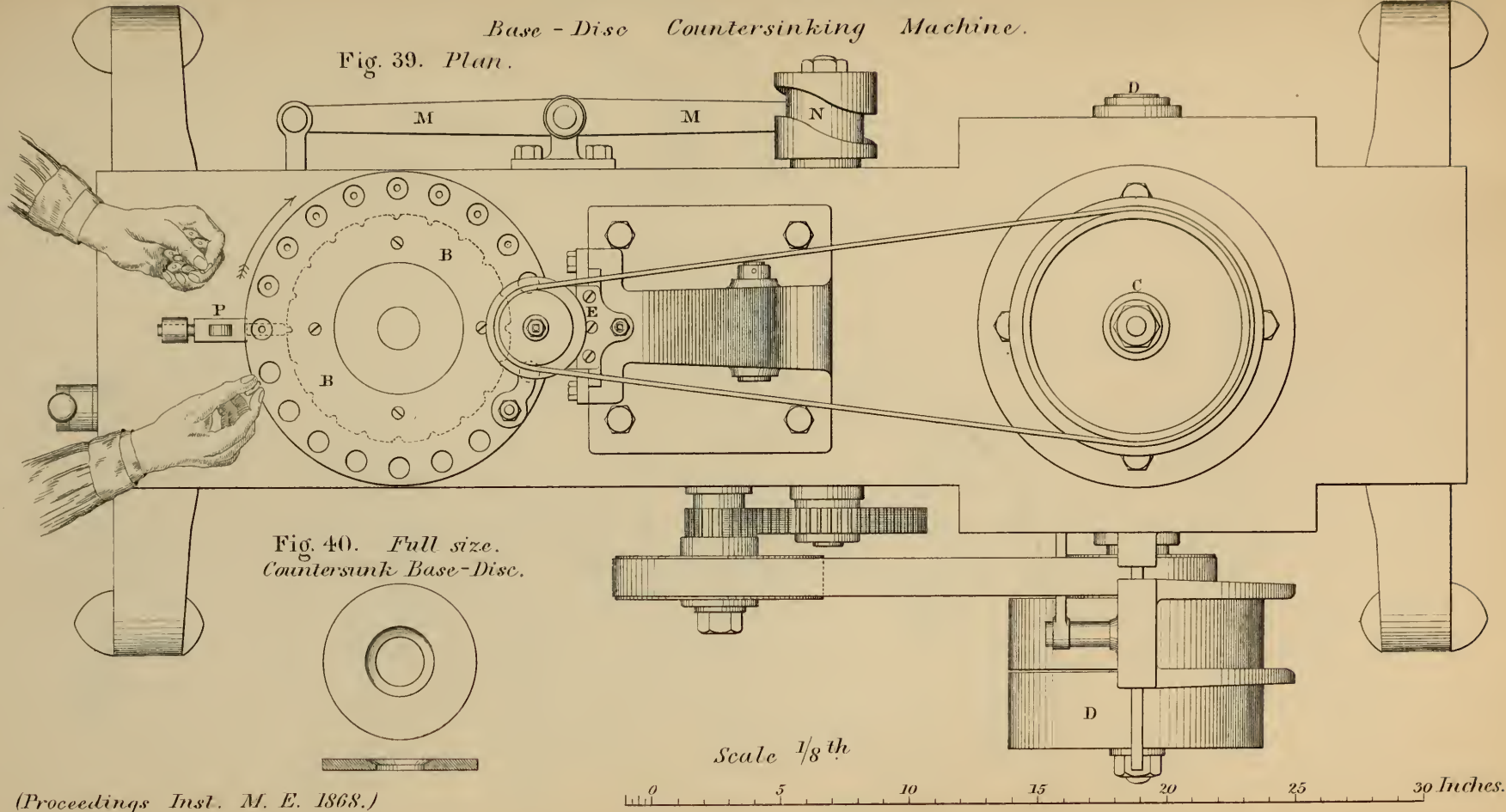


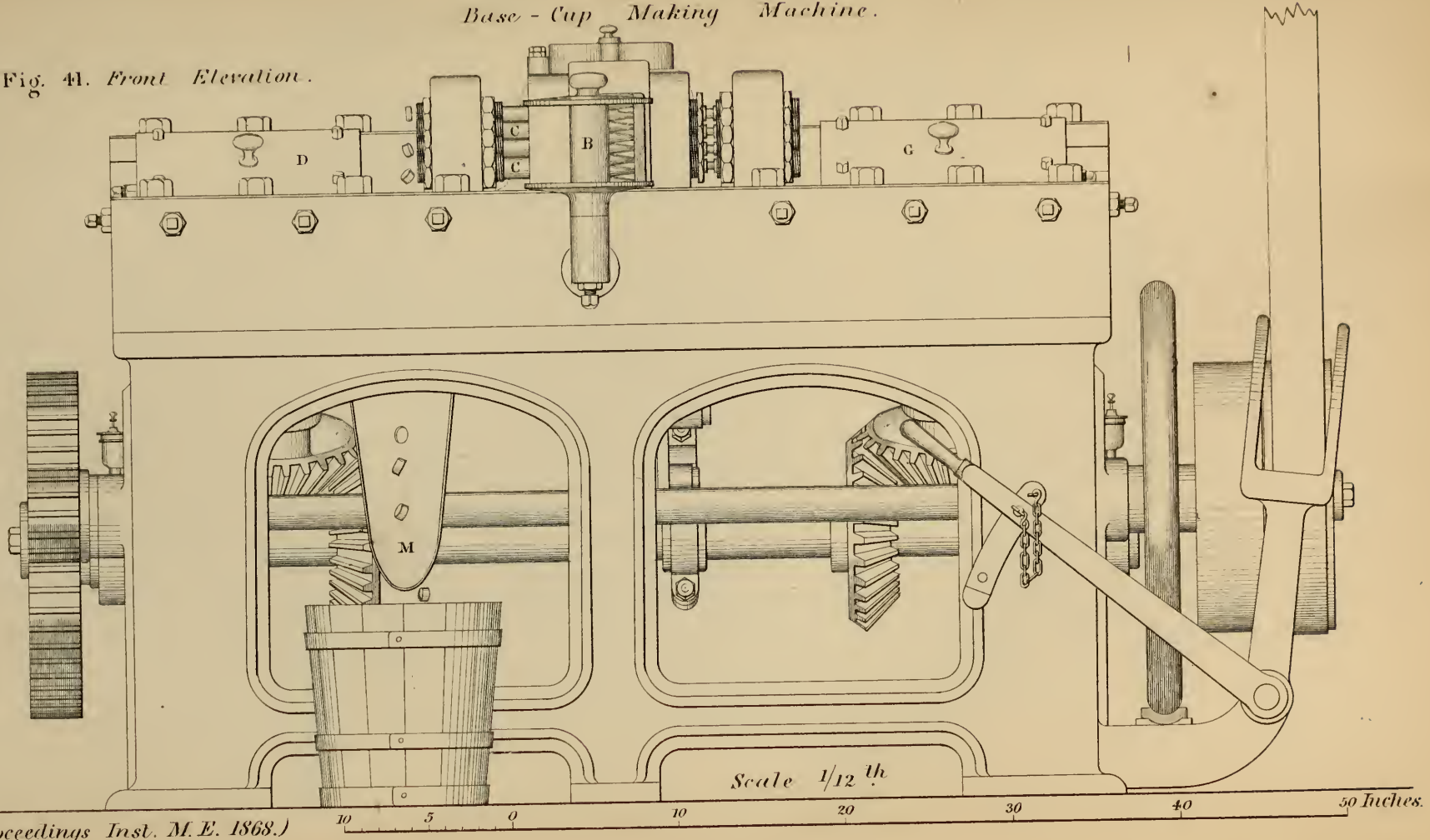
Fig. 40. *Full size.*
Countersunk Base-Disc.

(Proceedings Inst. M. E. 1868.)

CARTRIDGE MACHINERY.

Base - Cup Making Machine.

Fig. 41. *Front Elevation.*



(Proceedings Inst. M. E. 1868.)

Base-Cup Making Machine.

Fig. 42. *End Elevation.*

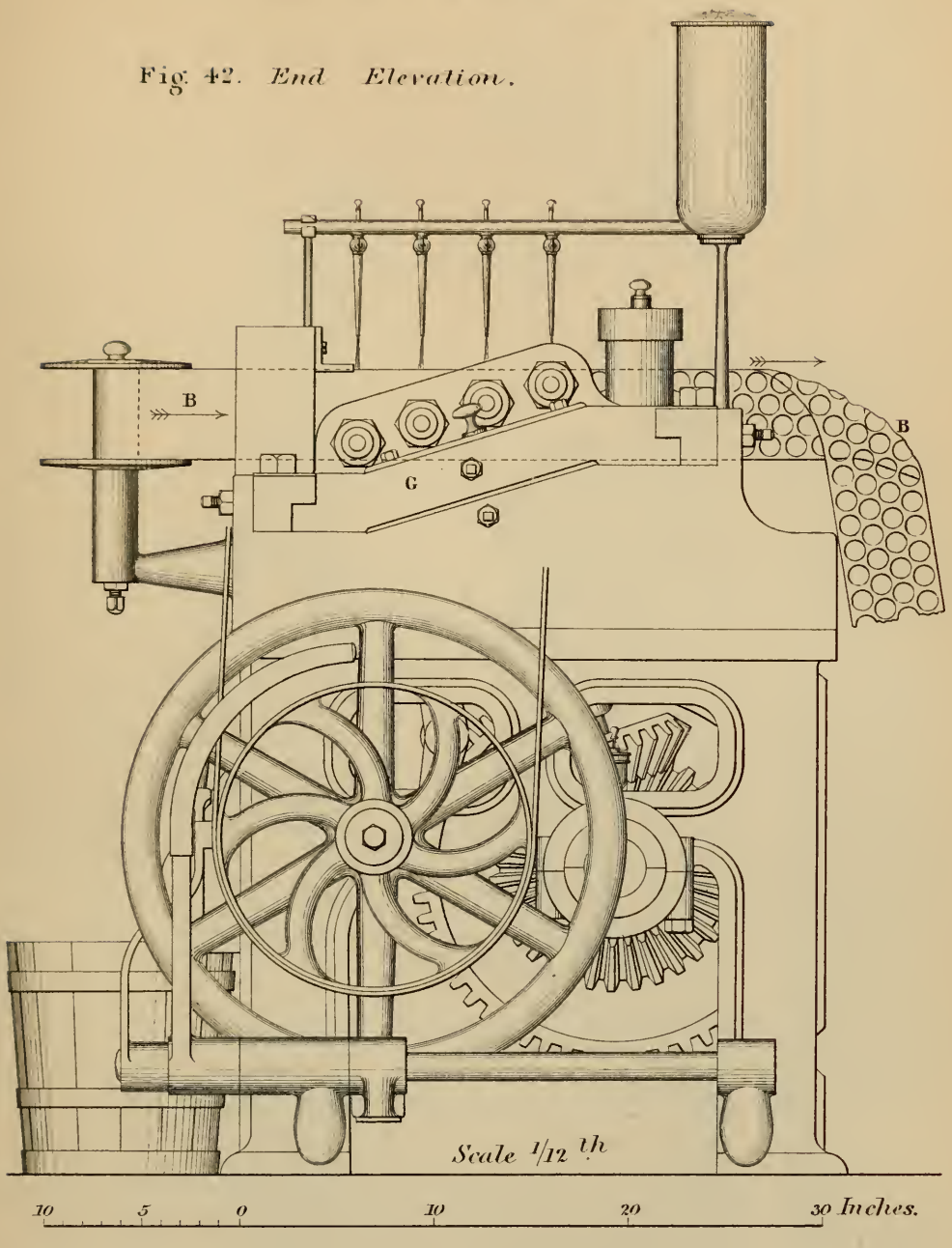


Fig. 43. *Deep Base-Cup, as delivered from machine.*

Full size.

(Proceedings Inst. M.E. 1868.)

Base-Cup Making Machine.

Fig. 44. *Longitudinal Section of Punches and Dies. Scale 1/12th*

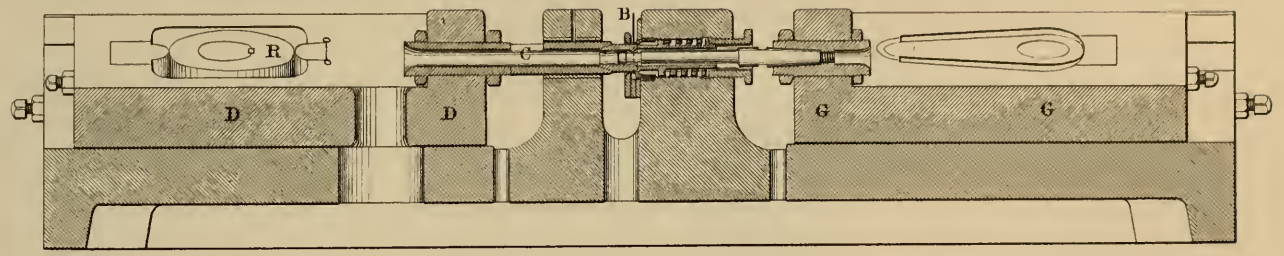
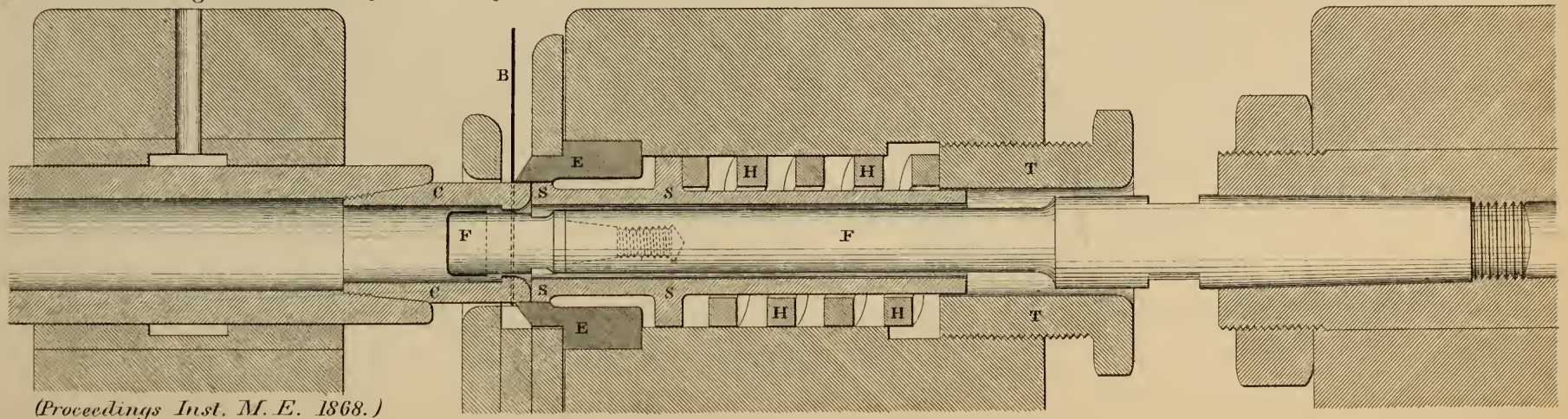


Fig. 45. *Enlarged Longitudinal Section of Punch and Bolster. Scale half full size.*



(Proceedings Inst. M. E. 1868.)

Hand Lever Press
for punching Hole in Base Cups.

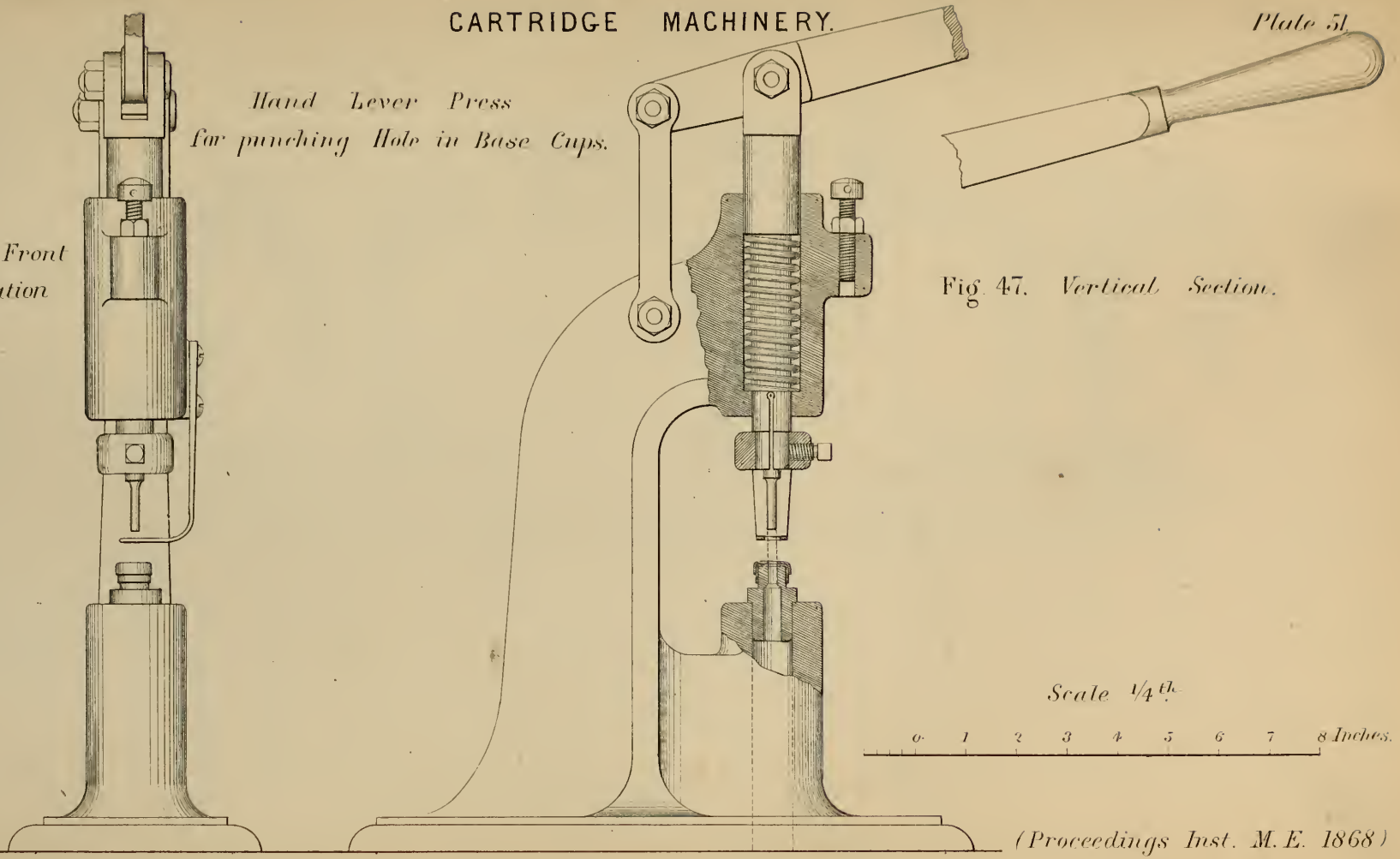


Fig. 46. *Front Elevation*

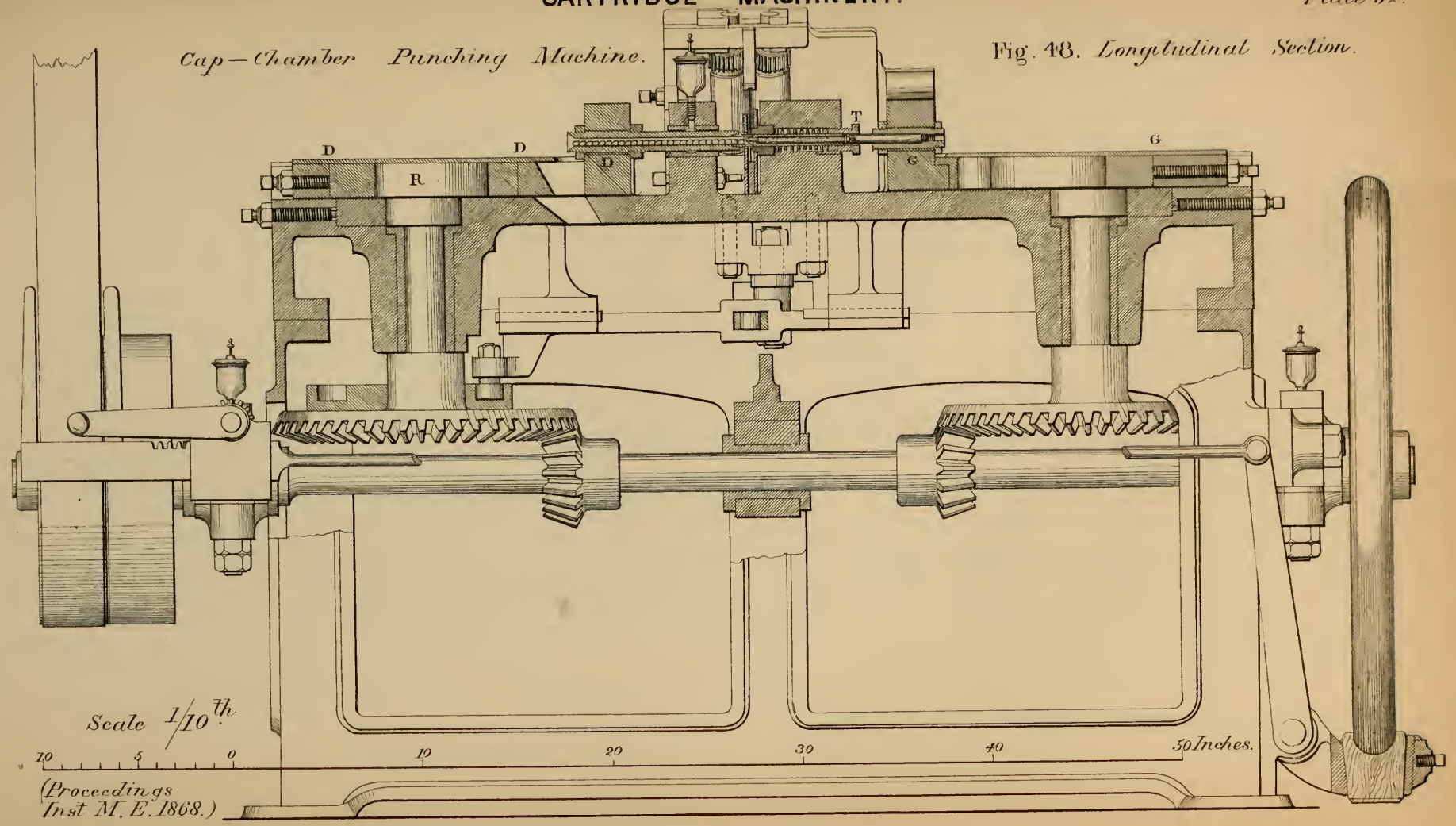
Fig. 47. *Vertical Section.*

Scale 1/4th.

0 1 2 3 4 5 6 7 8 *Inches.*

(Proceedings Inst. M.E. 1868)

Cap—Chamber Punching Machine. Fig. 48. *Longitudinal Section.*



(*Proceedings Inst M. E. 1868.*)

Cap—Chamber Punching Machine.

Fig. 49. *Transverse Section.*

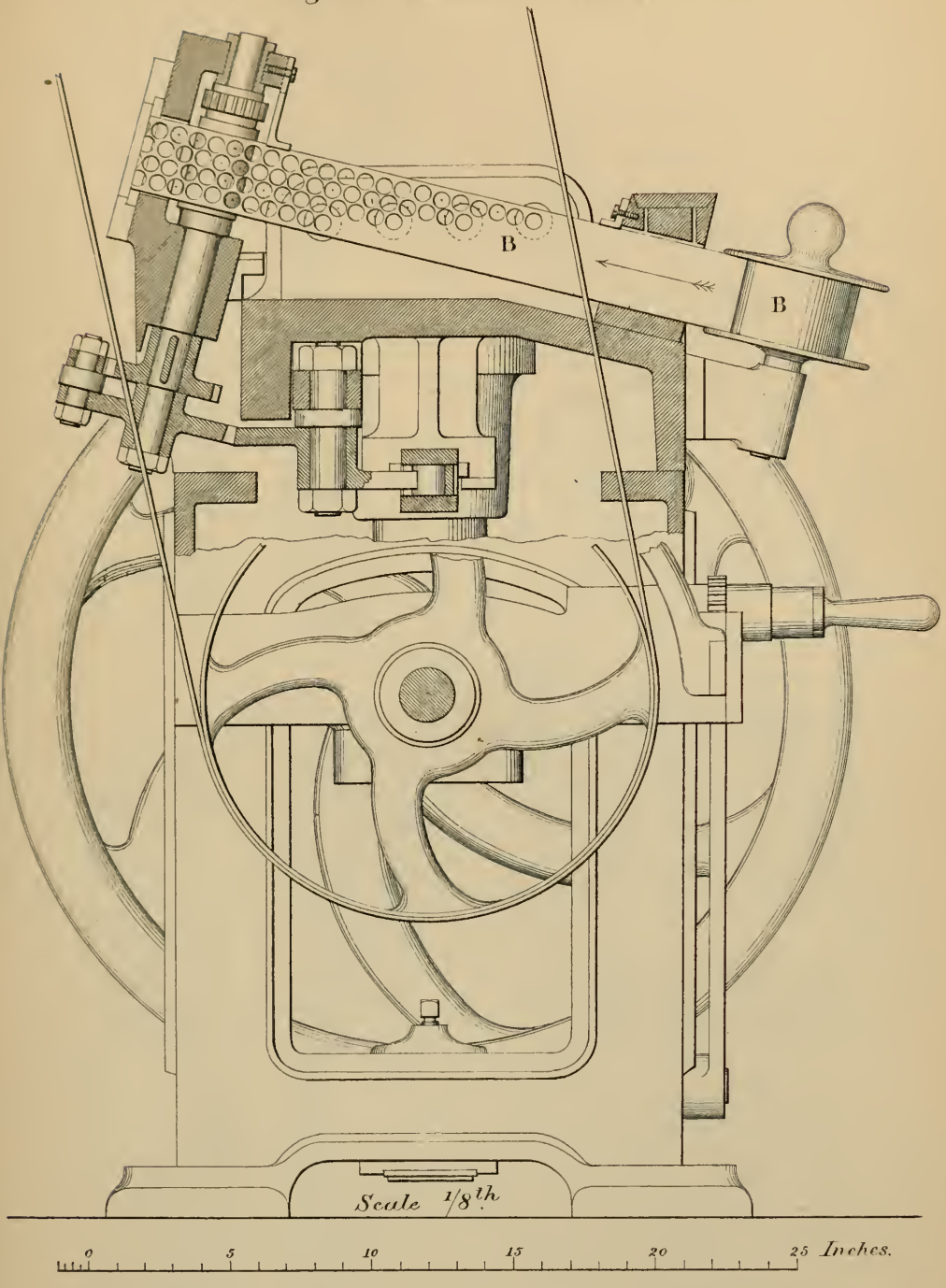
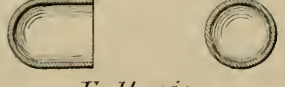


Fig. 50. *Cap—Chamber as delivered from machine.*



Full size.

(Proceedings Inst. M. E. 1868.)

CARTRIDGE MACHINERY.

Cap – Chamber Punching Machine.

Fig. 51. *Circular Flat Disc punched.*

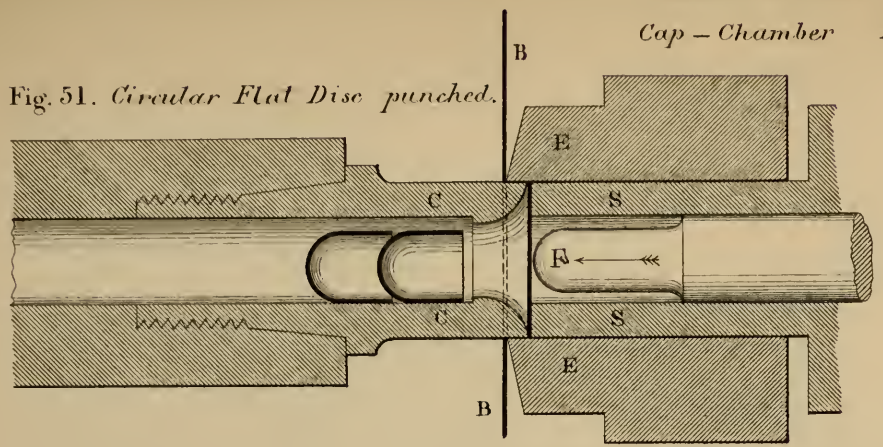
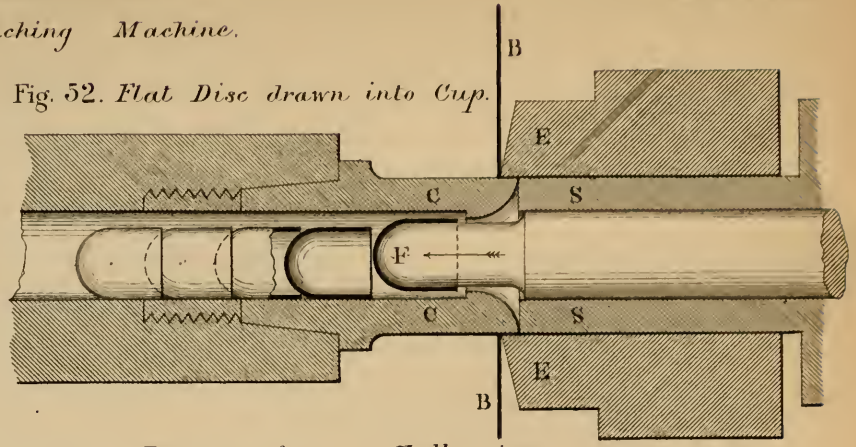
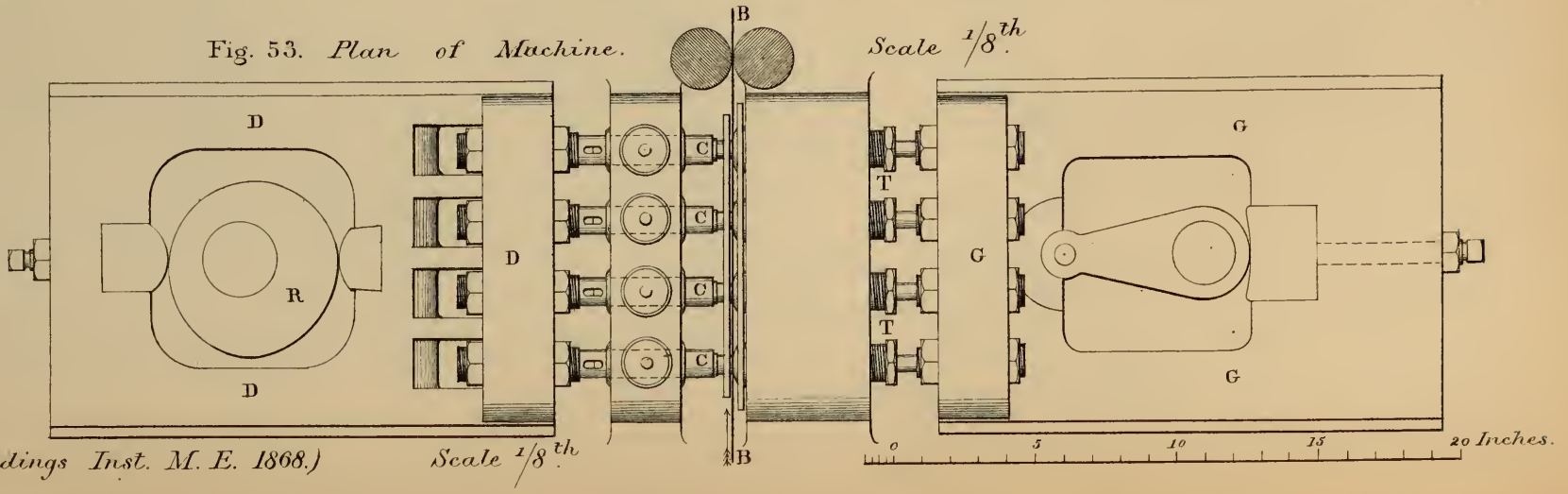


Fig. 52. *Flat Disc drawn into Cup.*



Longitudinal Sections of Punch and Bolster &c. Full size.

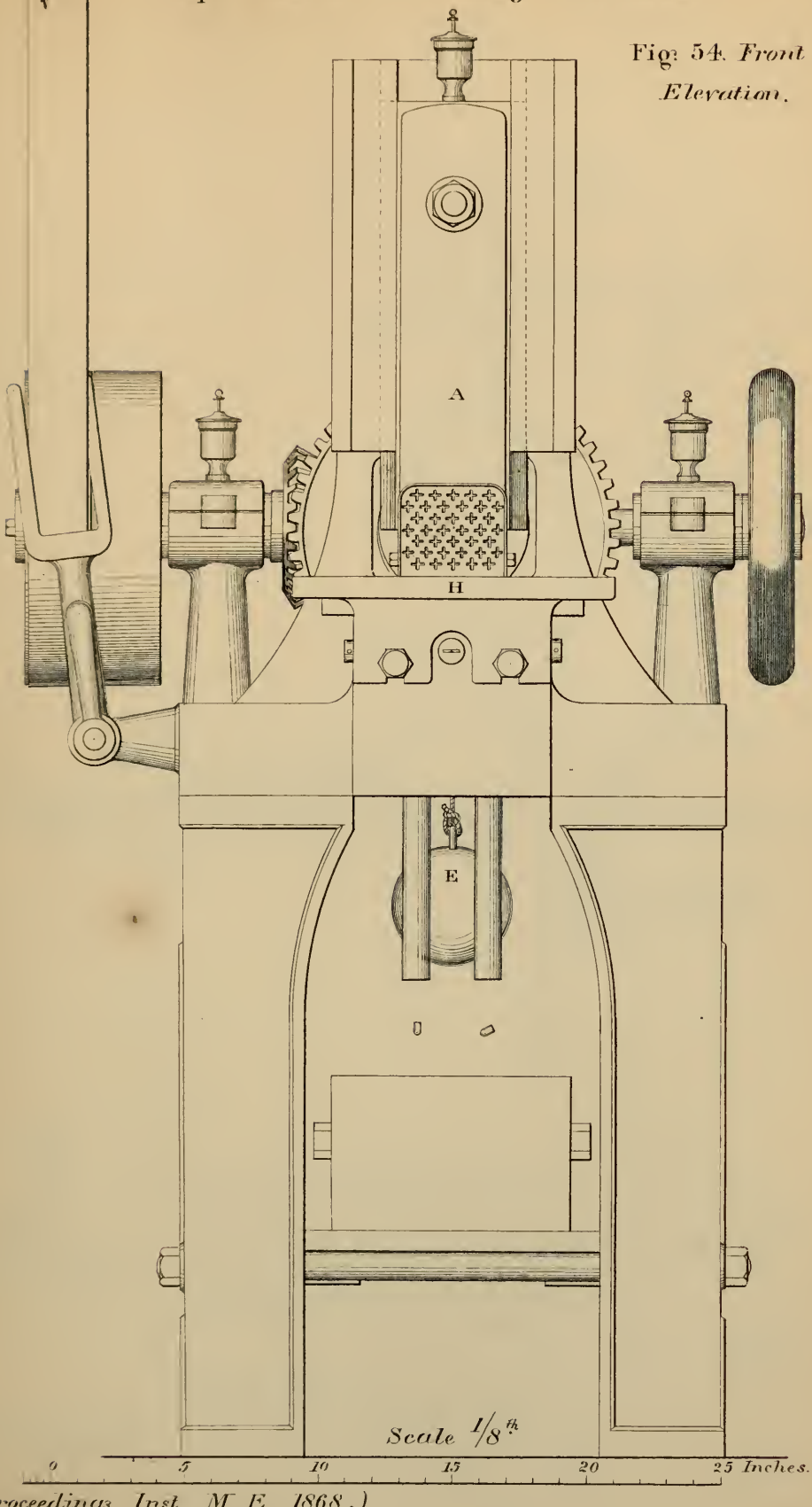
Fig. 53. *Plan of Machine.* *Scale 1/8th.*



(Proceedings Inst. M. E. 1868.) *Scale 1/8th.*

Cup-Chamber Drawing Machine.

Fig. 54. *Front Elevation.*



(Proceedings Inst. M. E. 1868.)

Cap-Chamber Drawing Machine.

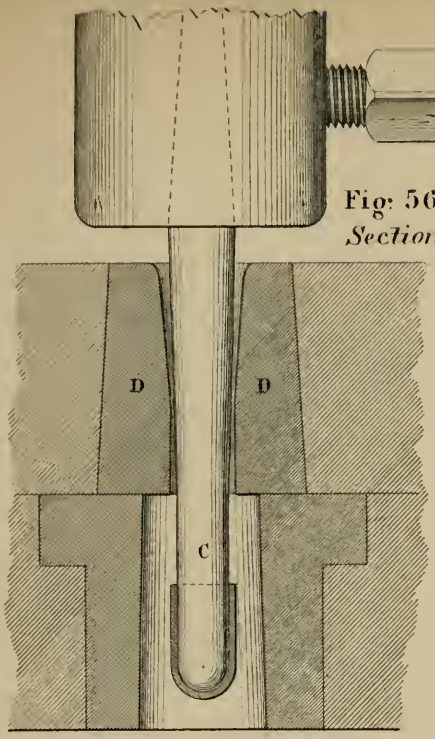


Fig: 56. *Vertical Section of Bolster.* *Full size.*

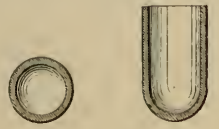
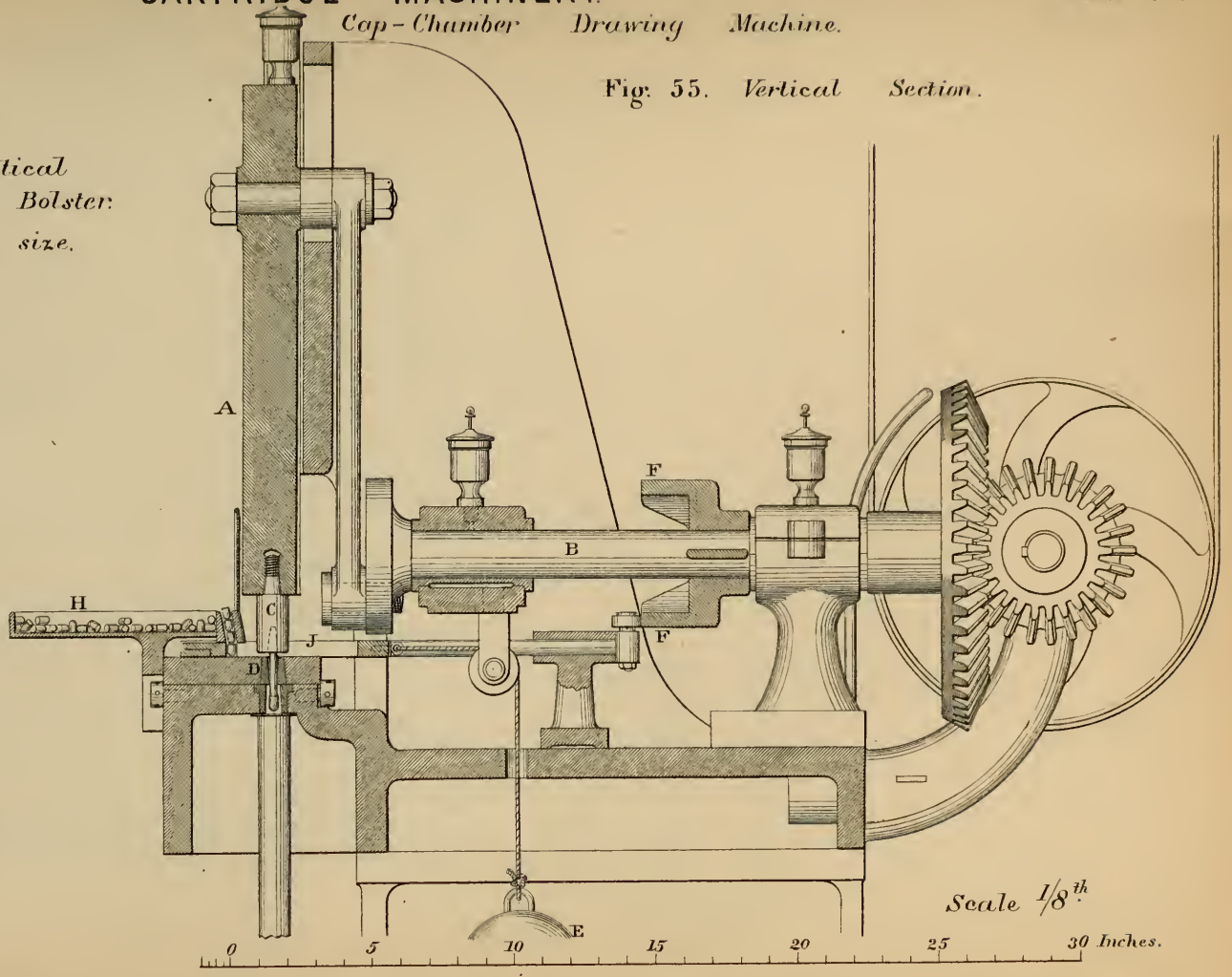


Fig: 57. *Cap Chamber. as delivered from machine.*

Full size.

Fig: 55. *Vertical Section.*



Scale 1/8th.

(Proceedings Inst. M. E. 1868.)

Cap-Chamber Trimming Machine.

Fig. 58. *Front Elevation, partly section.*

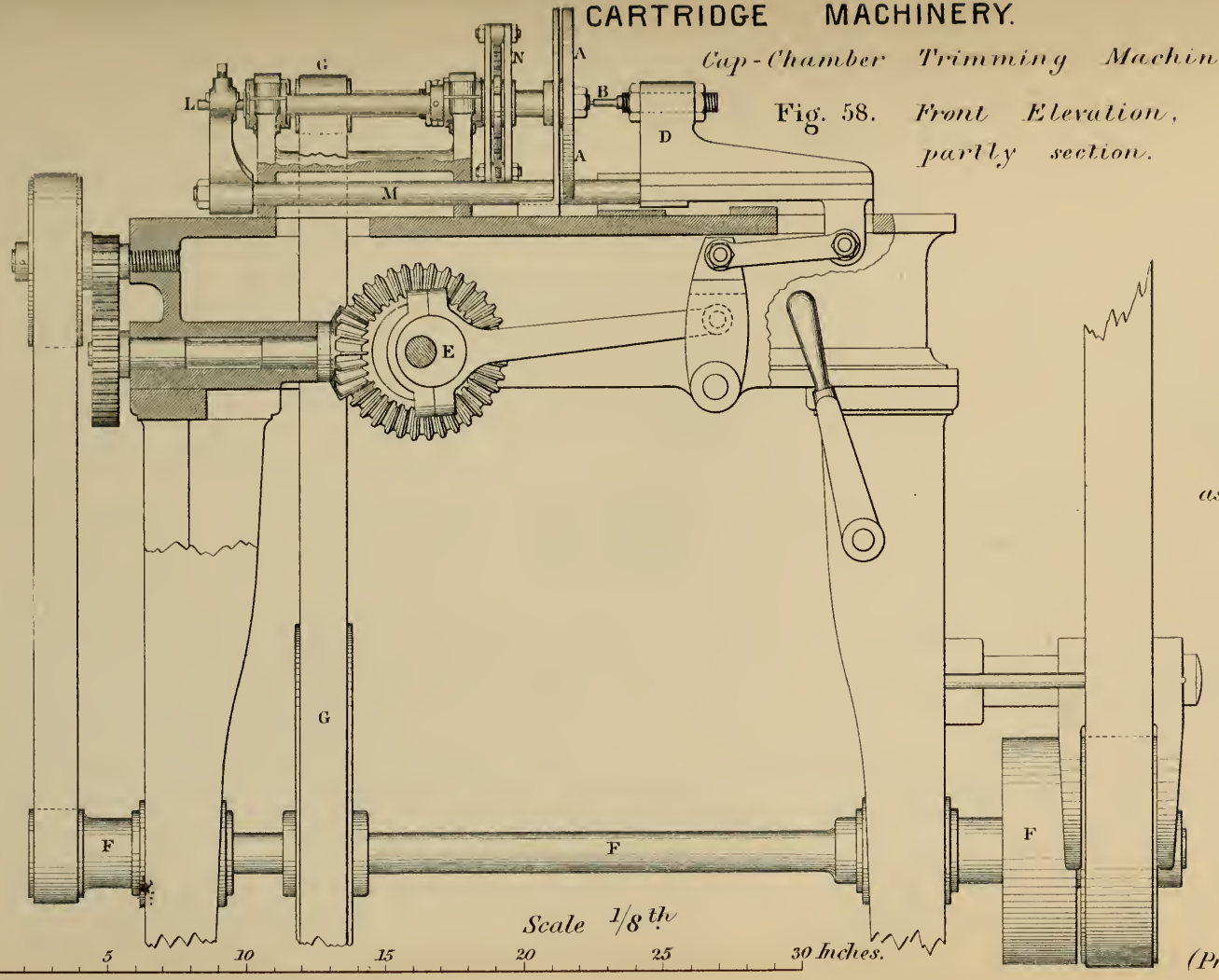


Fig. 59. *Cap Chamber as delivered from machine.*

Full size.

(Proceedings Inst. M. E. 1868.)

CARTRIDGE MACHINERY.

Cap-Chamber Trimming Machine.

Fig. 60. *Plan.*
Scale 1/8th

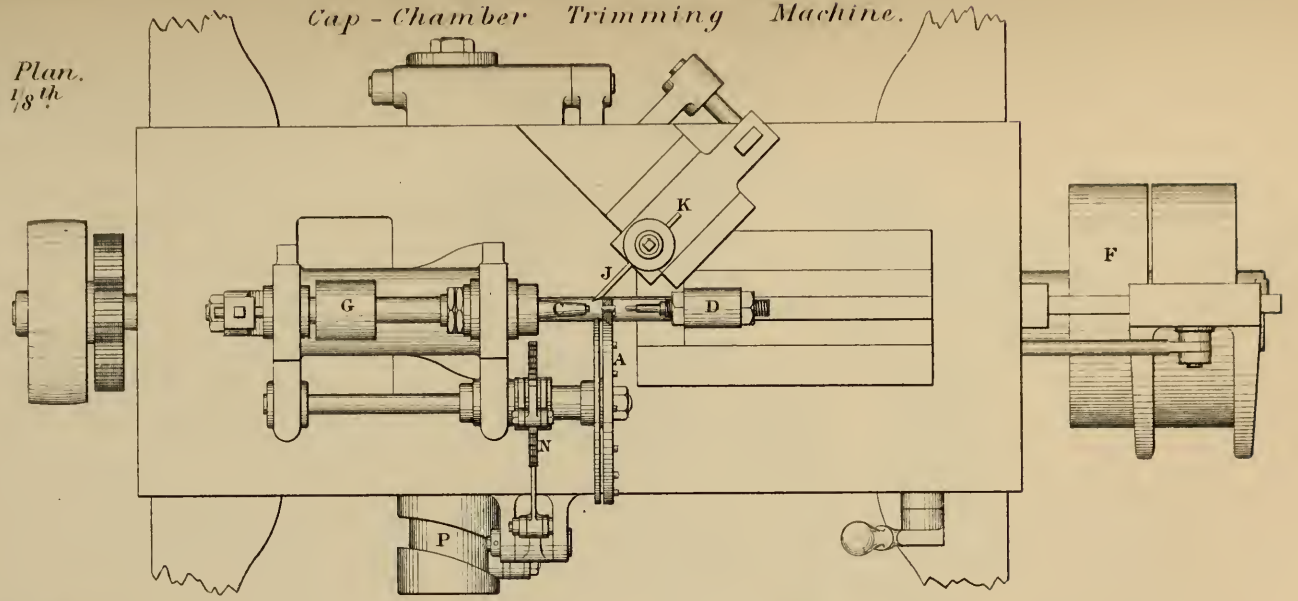
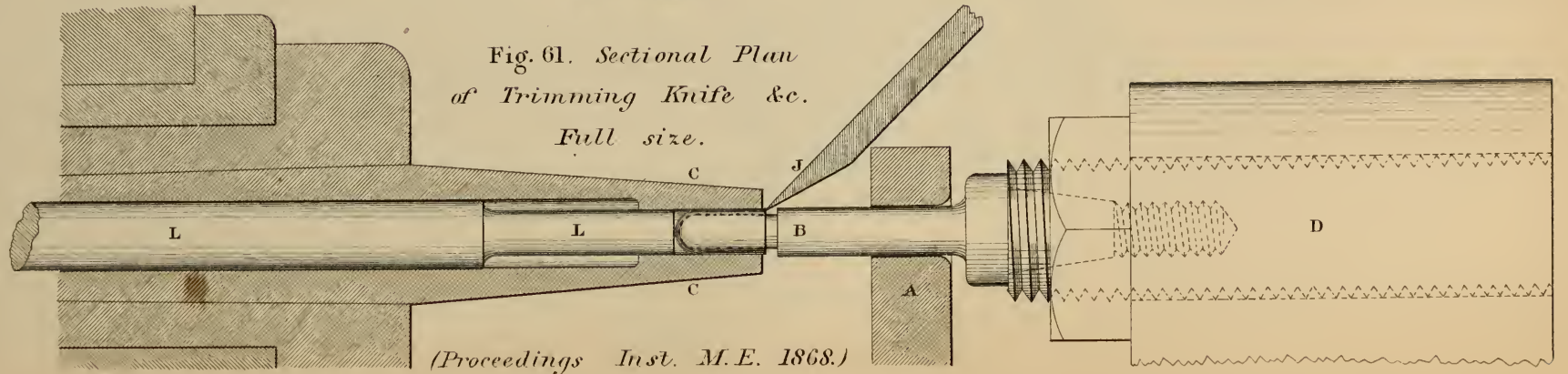


Fig. 61. *Sectional Plan of Trimming Knife &c.*
Full size.



(Proceedings Inst. M.E. 1868.)

Cap – Chamber Flanging Machine.

Fig. 62. *Vertical Section.*

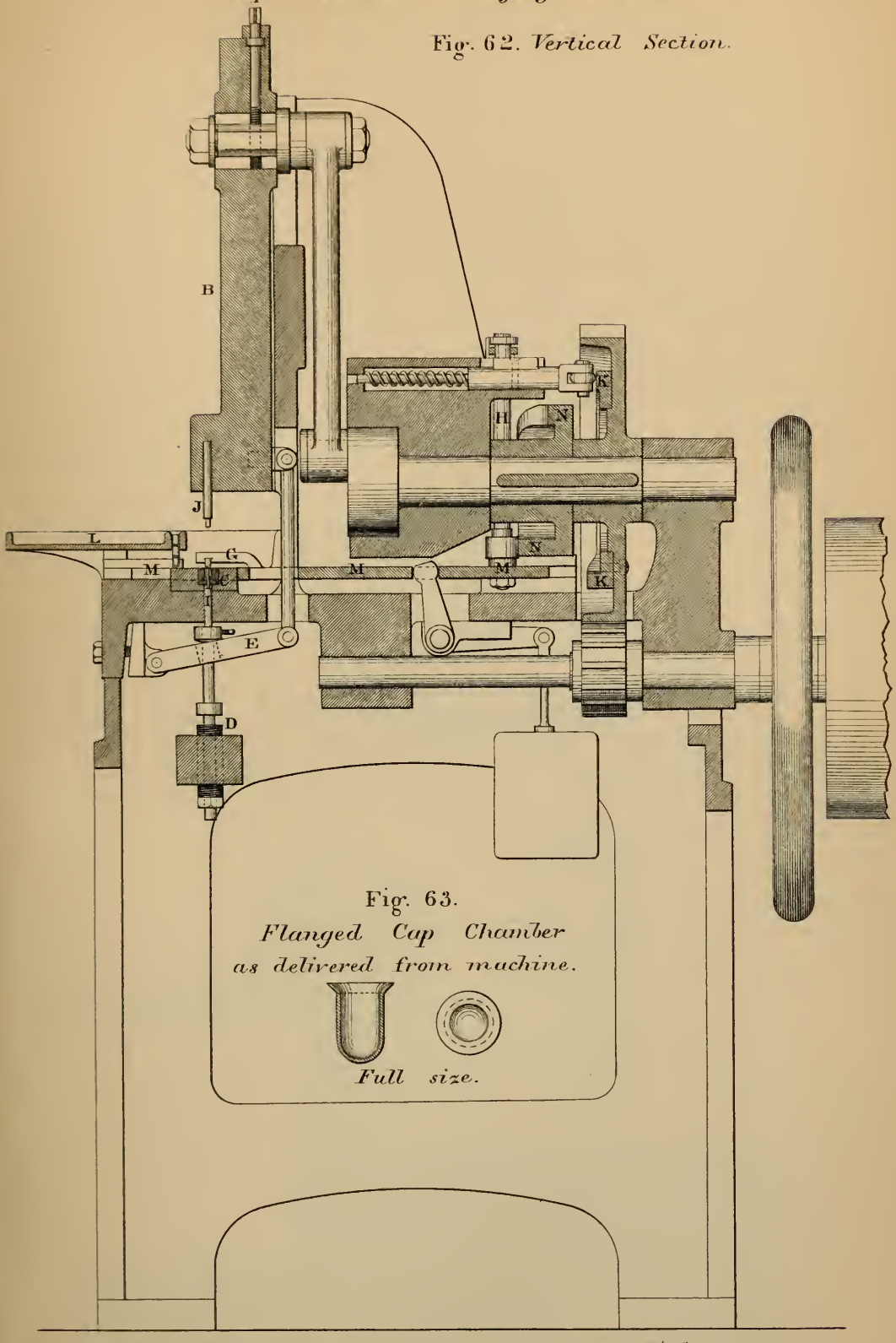


Fig. 63.

Flanged Cap Chamber as delivered from machine.

Full size.

(Proceedings Inst. M. E. 1868.) *Scale 1/8th*

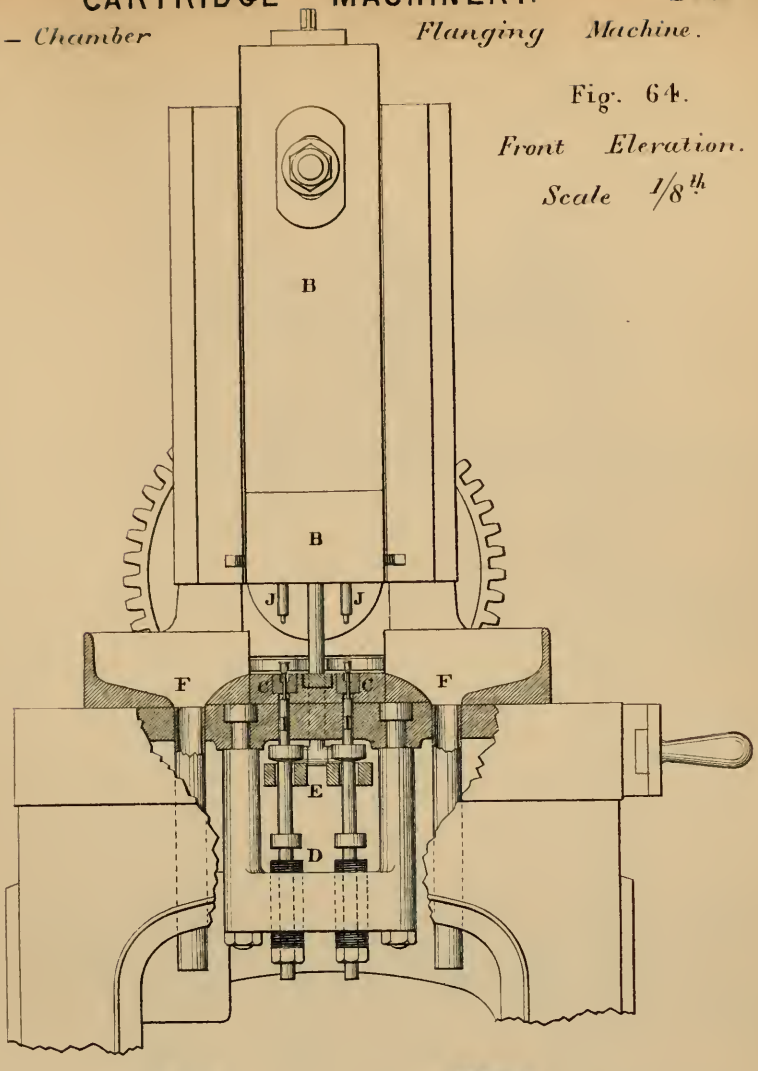
0 5 10 15 20 25 Inches.

Cap – Chamber Flanging Machine.

Fig. 64.

Front Elevation.

Scale 1/8th



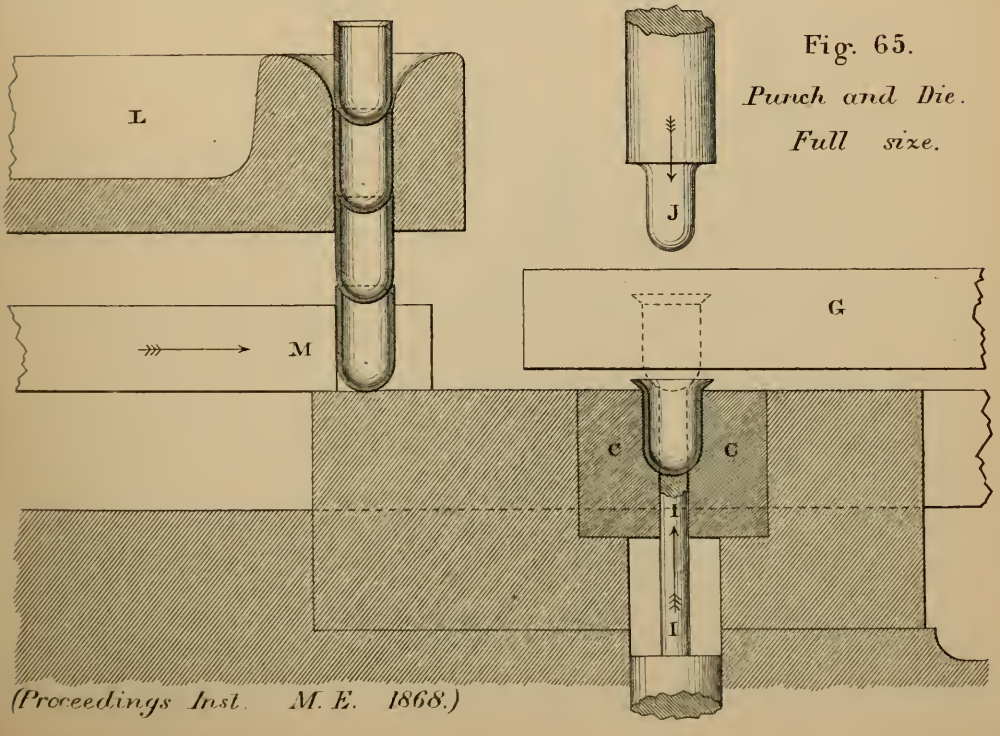


Fig. 65.

Punch and Die.

Full size.

(Proceedings Inst. M. E. 1868.)

Paper Wad Making Machine.

Fig. 66. *Side Elevation.*

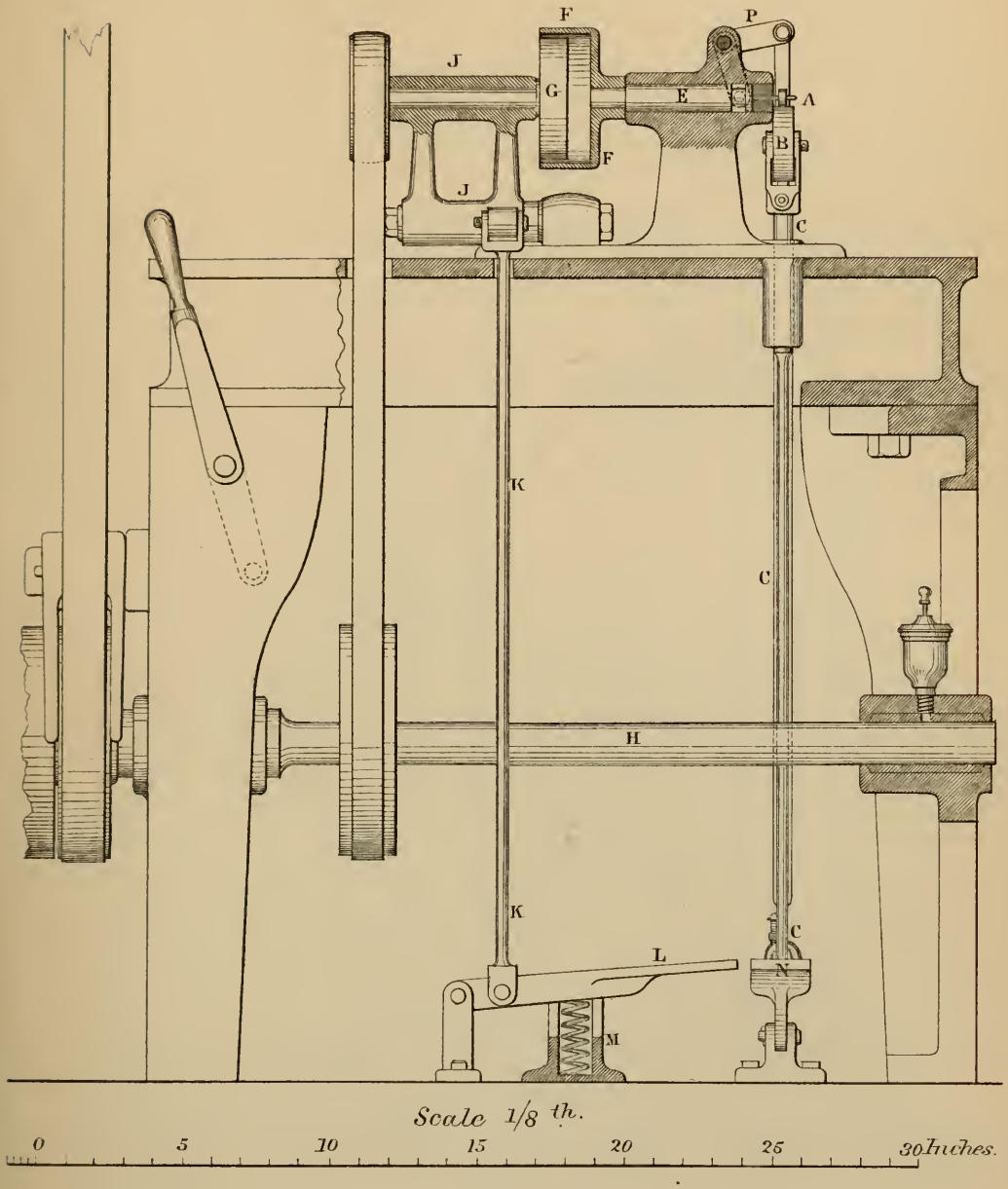
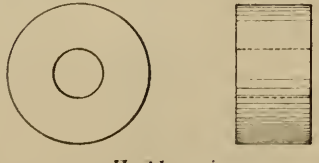


Fig. 67. *Paper Wad, as delivered from machine.*

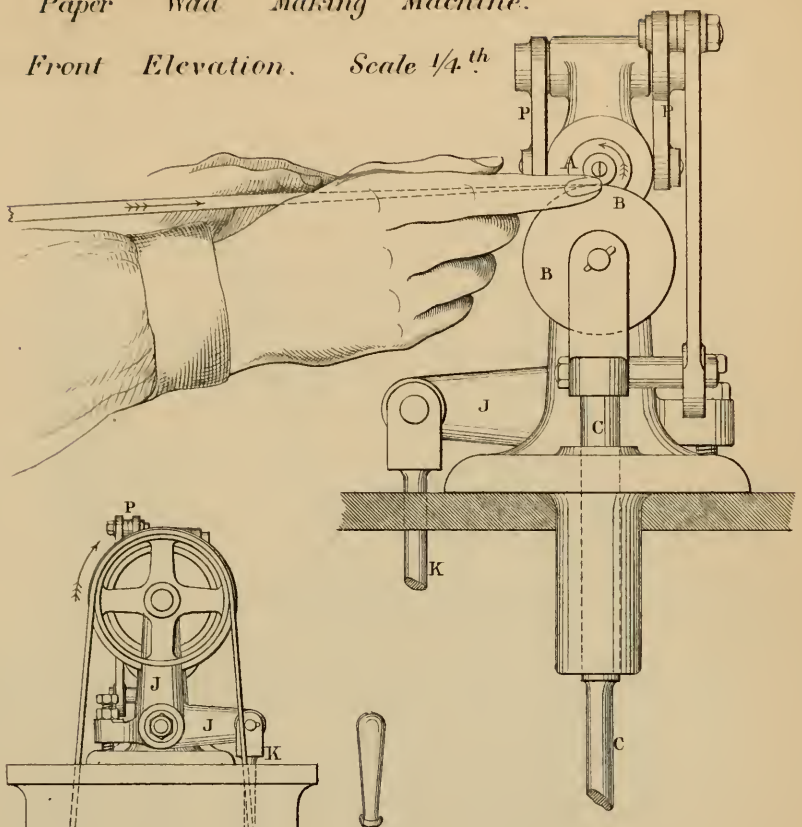


Full size.

(Proceedings Inst. M. E. 1868.)

Paper Wad Making Machine.

Fig. 68. *Front Elevation. Scale 1/4 th.*



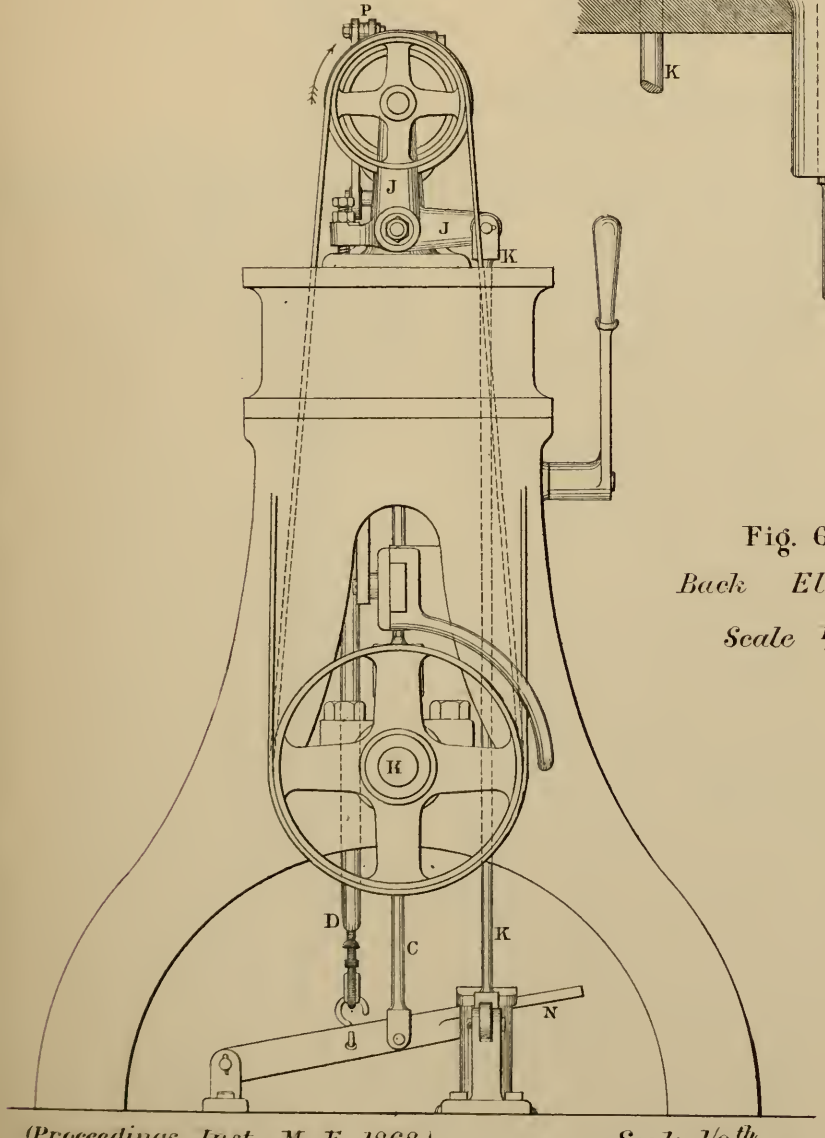


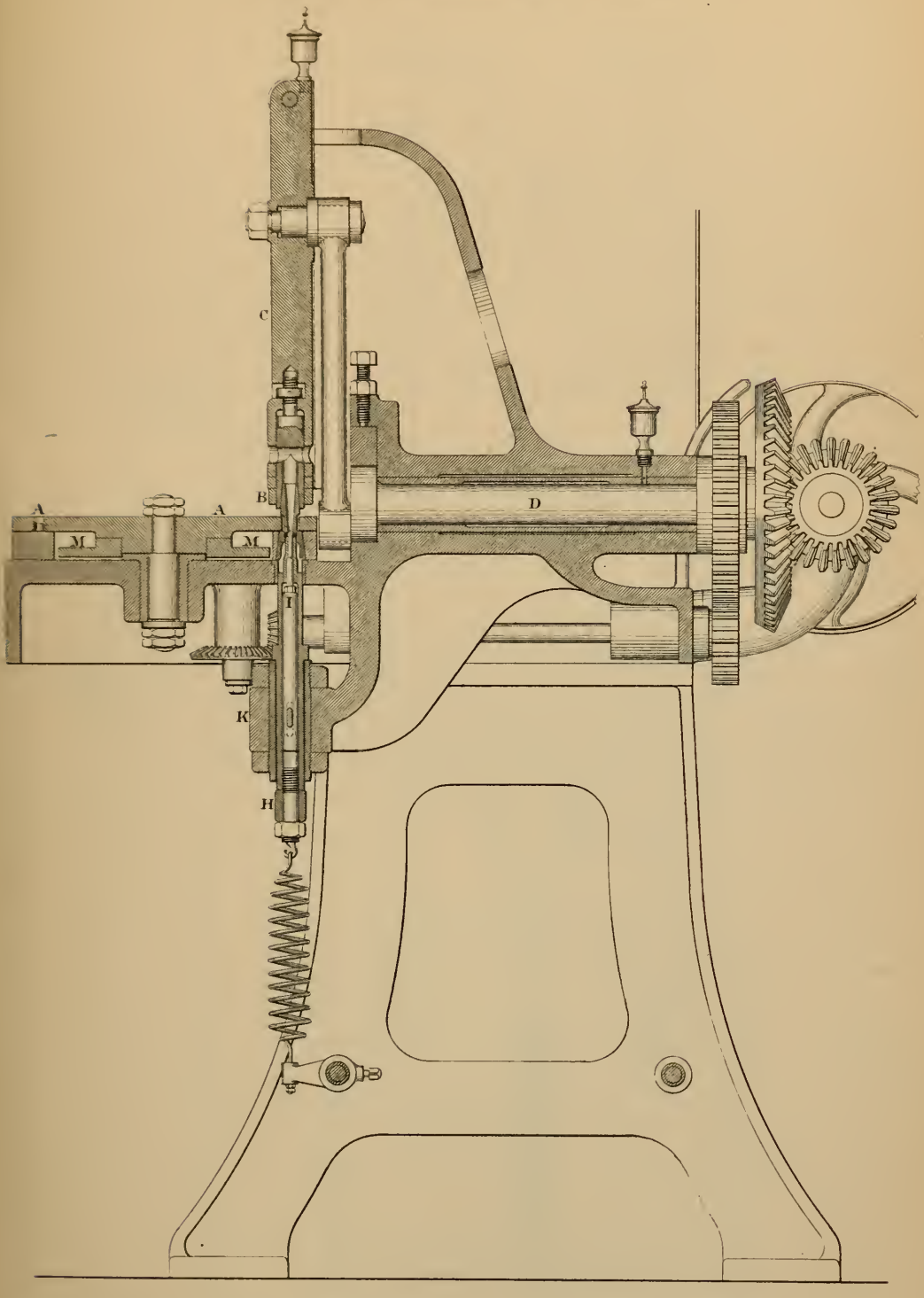
Fig. 69.
Back Elevation.
Scale 1/8 th.

(Proceedings Inst. M. E. 1868) *Scale 1/8 th.*

0 5 10 15 20 25 30 Inches.

Paper Wad Pressing Machine.

Fig. 70. *Longitudinal Section.*

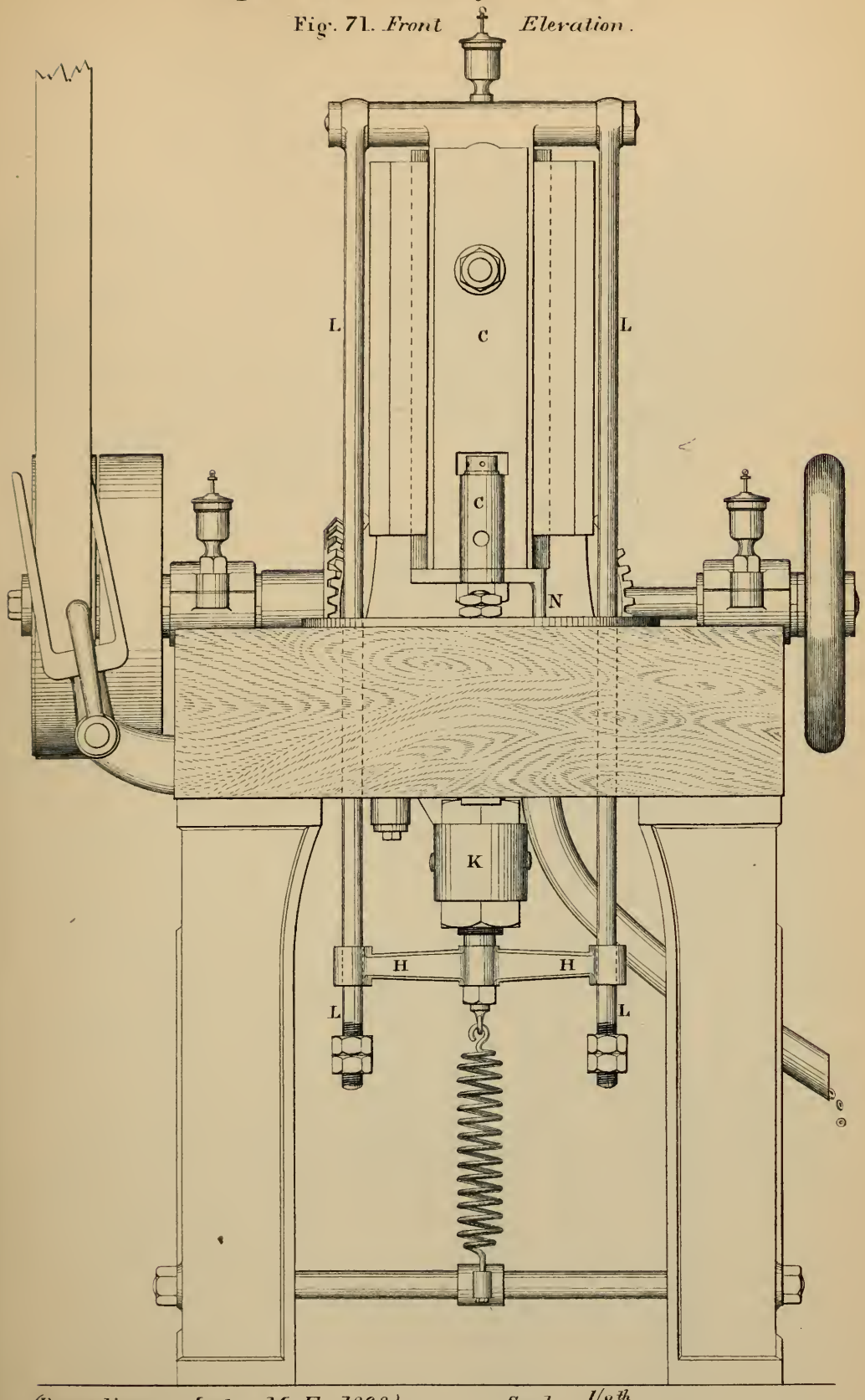


(Proceedings Inst. M. E. 1868.) *Scale* $^1/_{10}$ *th*

0 5 10 15 20 25 30 *Inches.*

Paper Wad Pressing Machine.

Fig. 71. *Front Elevation.*



(Proceedings Inst. M. E. 1868.) *Scale* 1/8th

0 5 10 15 20 25 30 Inches.

Paper Wad Pressing Machine.

Fig. 72. *Scale 1/4th*
Plan of Star Wheel for rotating the Feed Table.

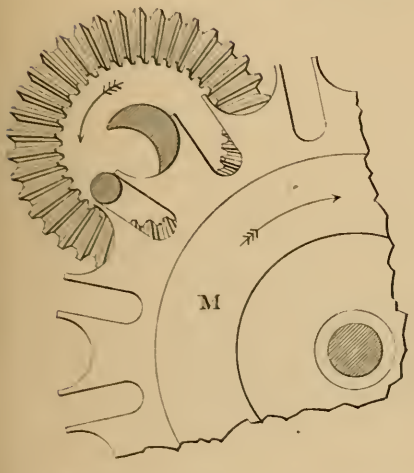
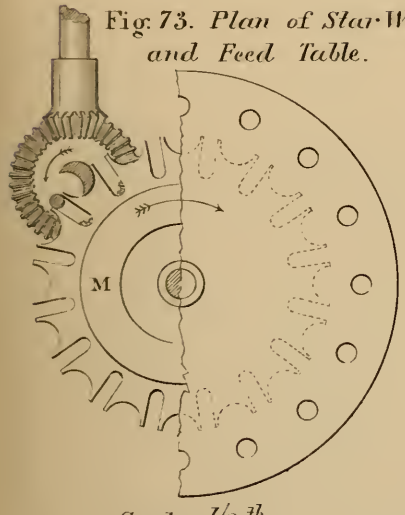


Fig. 73. *Plan of Star-Wheel and Feed Table.*



Scale 1/8th

Fig. 74. *Full size Vertical Section of Pressing Punch and Die.*

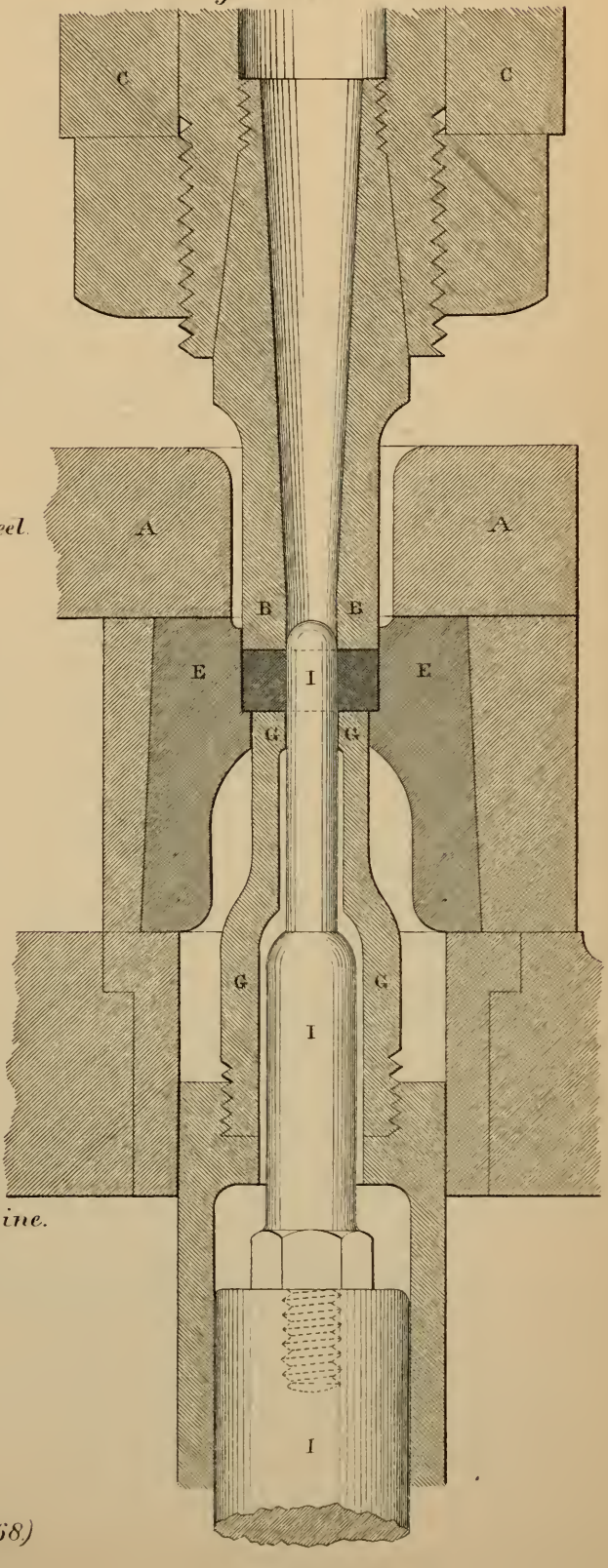
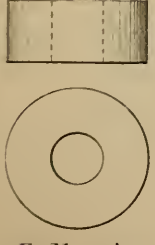


Fig. 75. *Pressed Wad as delivered from machine.*



Full size.

(Proceedings Inst. M. E. 1868)

Hand Lever Press for fixing body of Cartridge together.

Fig. 76. *Longitudinal Section.* *Scale 1/4th.*

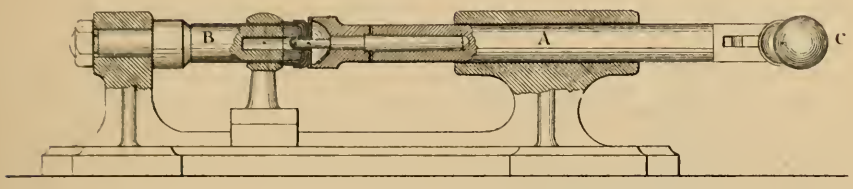
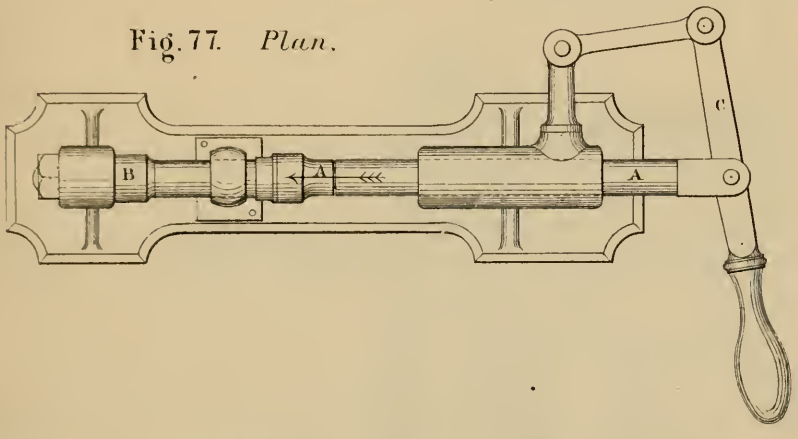


Fig. 77. *Plan.*



Choking Apparatus for fixing Bullet in Cartridge Case.

Fig. 78. *Side Elevation.*

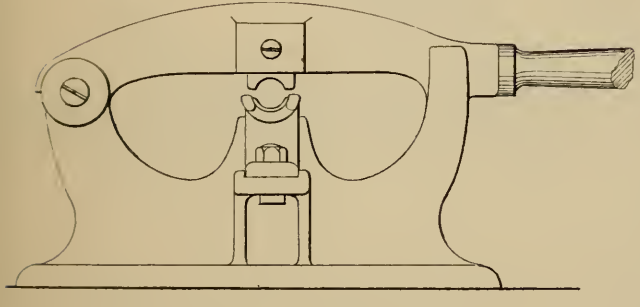


Fig. 79. *Transverse Section.*

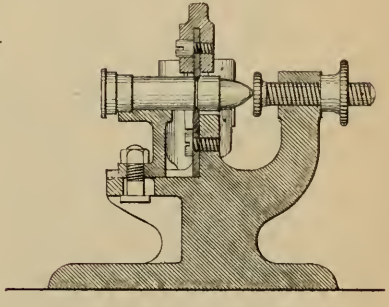
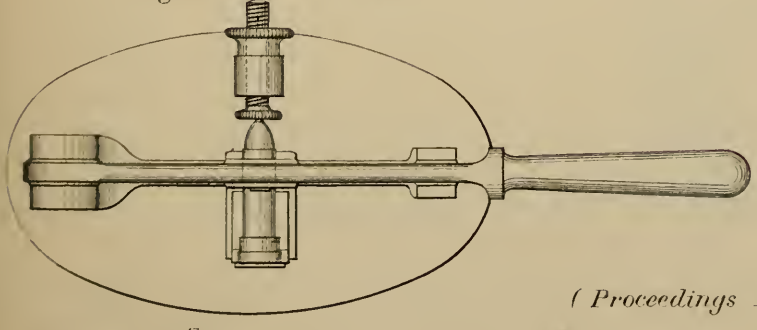


Fig. 80. *Plan.*

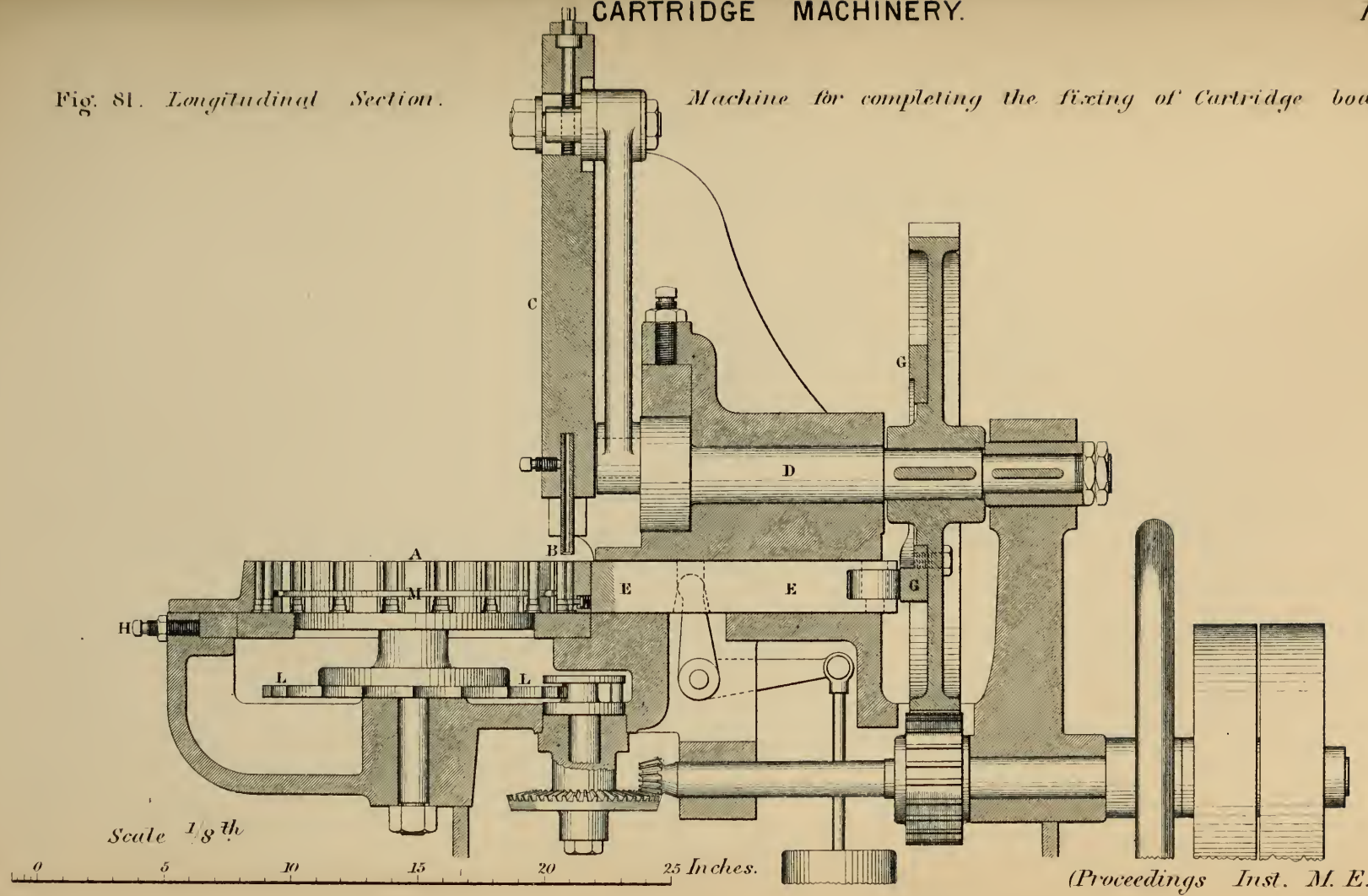


(Proceedings Inst. M.E. 1868.)

Scale 1/4th.

0 1 2 3 4 5 6 7 8 9 10 *Inches.*

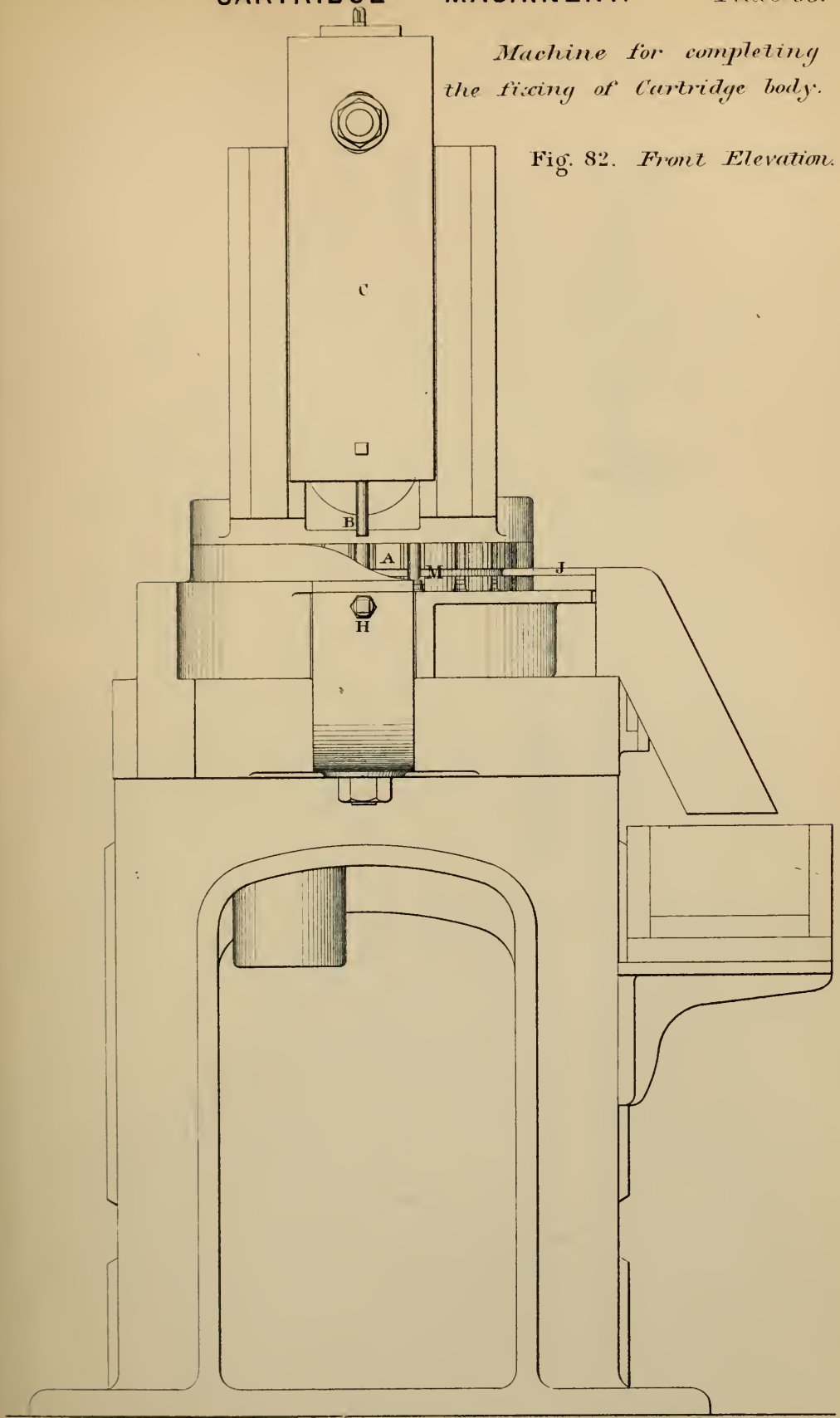
Fig. 81. *Longitudinal Section.* *Machine for completing the fixing of Cartridge body.*



(Proceedings Inst. M. E. 1868.)

Machine for completing the fixing of Cartridge body.

Fig. 82. *Front Elevation.*



(Proceedings Inst. M. E. 1868.) *Scale 1/8th*

0 5 10 15 20 25 Inches.

Machine for completing the fixing of Cartridge body.

Fig. 83. *Plan of Feed Plate.*
Scale 1/8 th

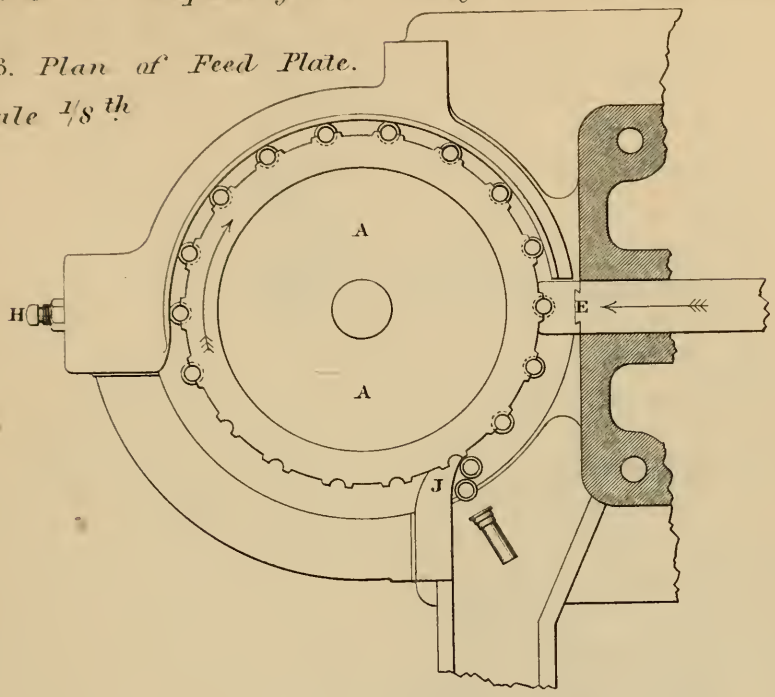
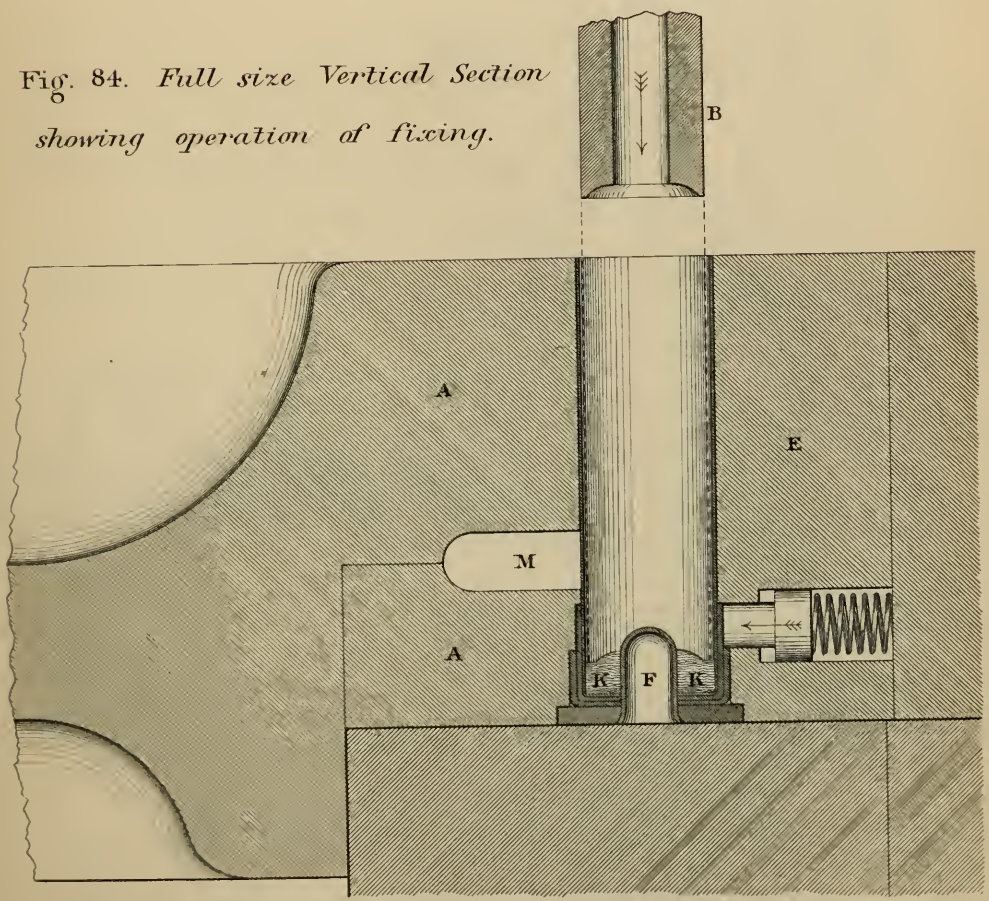


Fig. 84. *Full size Vertical Section showing operation of fixing.*

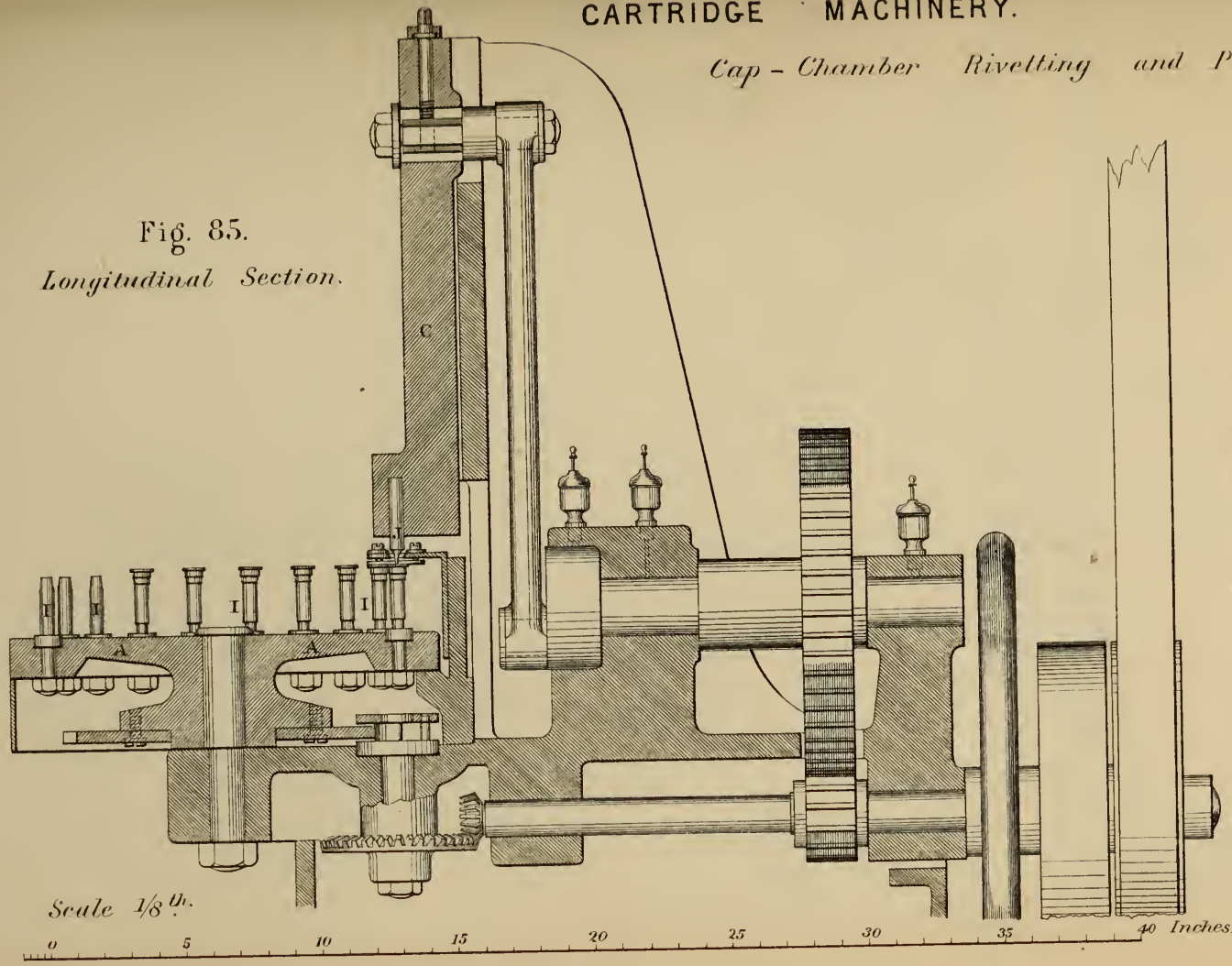


(Proceedings Inst. M. E. 1868.) *Full size.*

Cap-Chamber Rivetting and Piercing Machine.

Fig. 85.

Longitudinal Section.



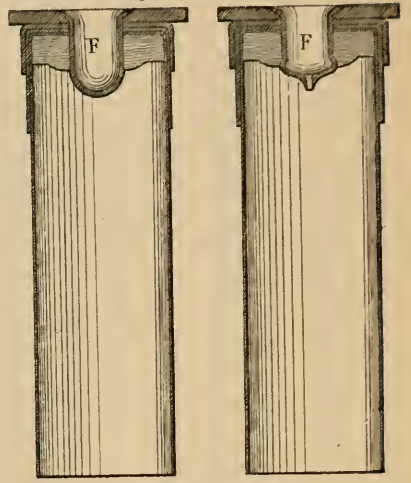
Scale 1/8 th.

0 5 10 15 20 25 30 35 40 Inches.

Full size Sections of Cartridge Case.

Fig. 86. *Before Rivetting.*

Fig. 87. *After Rivetting and Piercing*



Thicknesses magnified.

(Proceedings Inst. M. E. 1868.)

CARTRIDGE MACHINERY.

Cap-Chamber Rivetting and Piercing Machine.

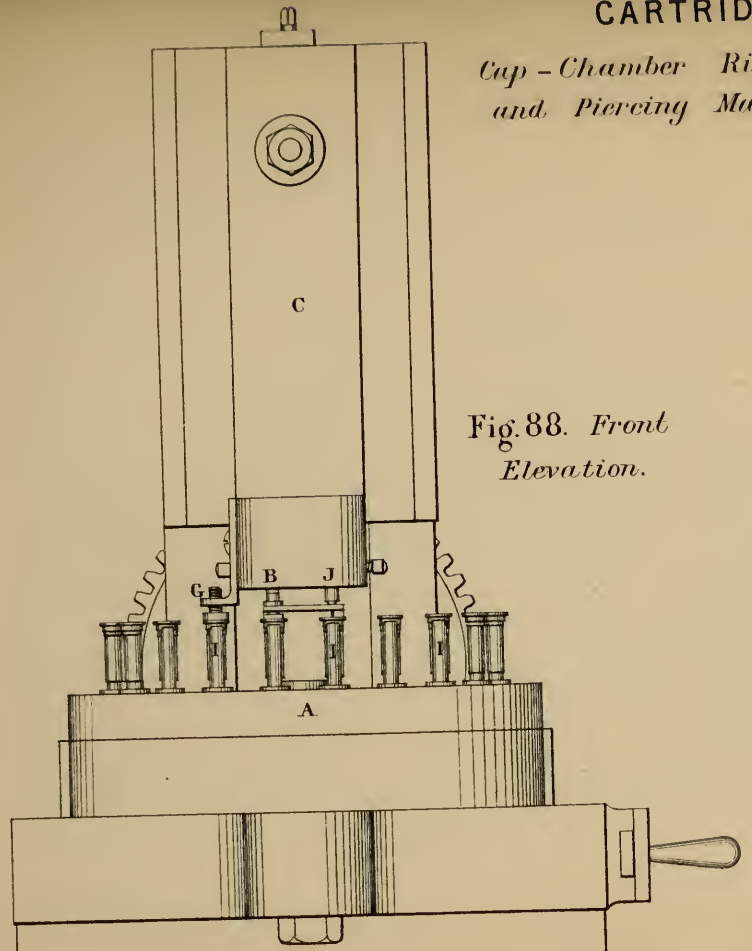


Fig. 88. *Front Elevation.*

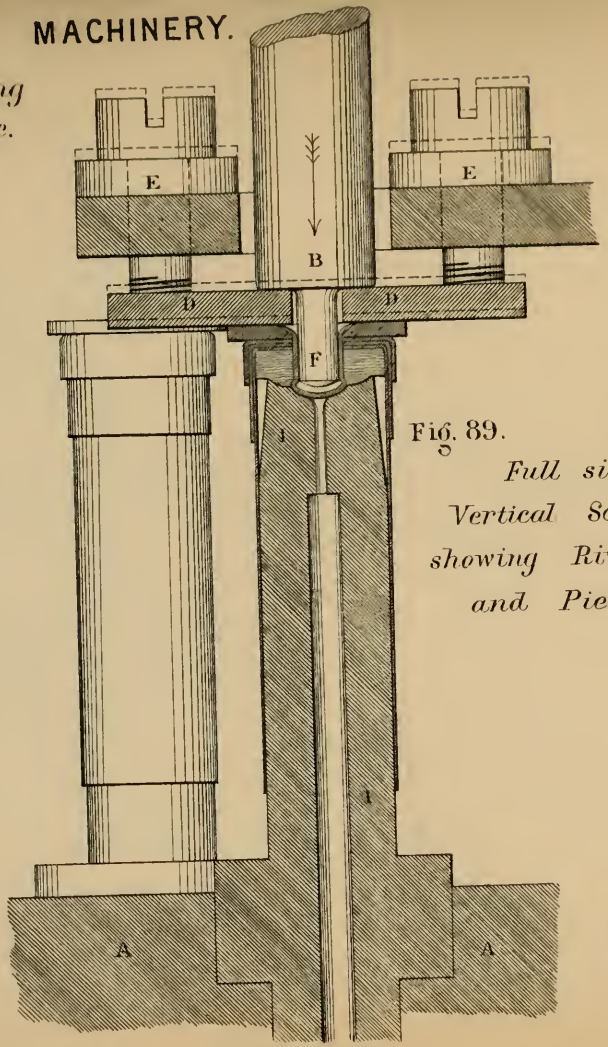


Fig. 89.

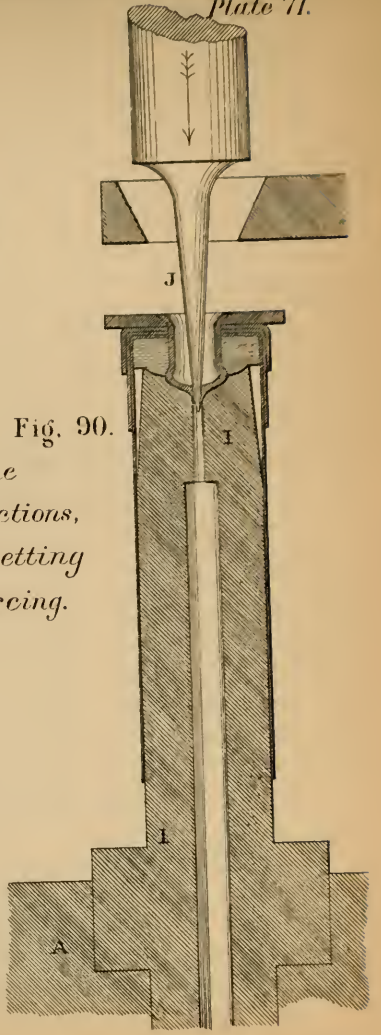


Fig. 90.

Full size Vertical Sections, showing Rivetting and Piercing.

(Proceedings Inst. M. E. 1868.) *Scale 1/8th.*

0 5 10 15 20 Inches.

Capping Machine.

Fig. 91. *Plan.*

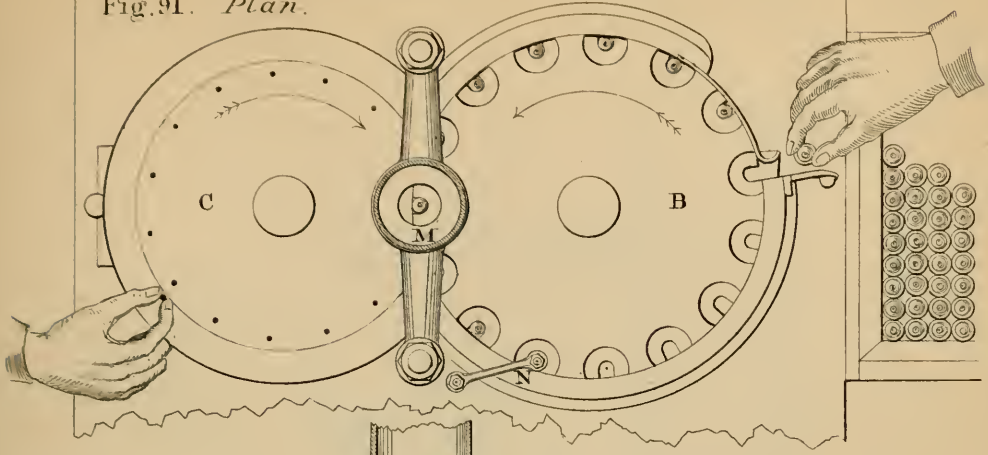
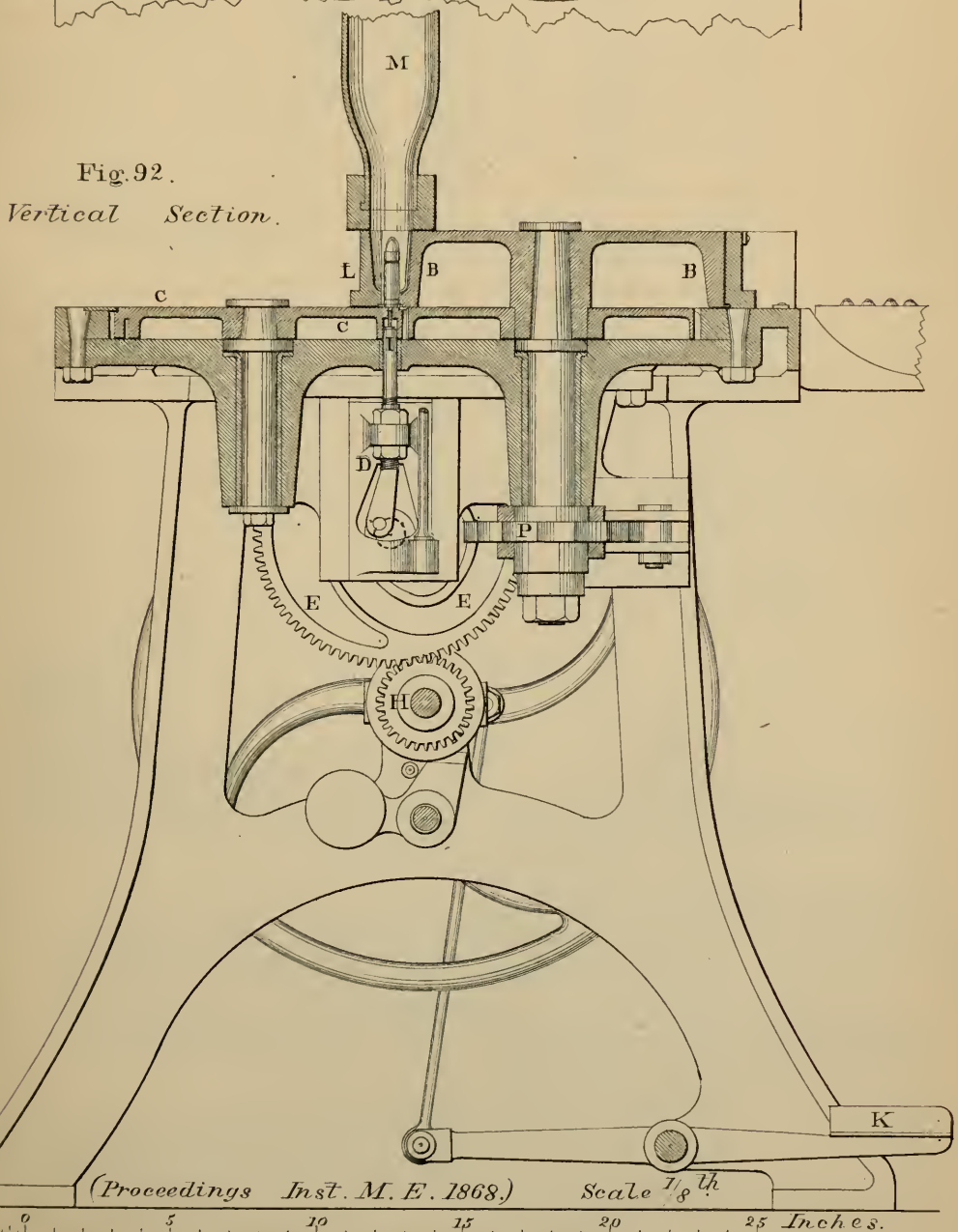


Fig. 92.
Vertical Section.



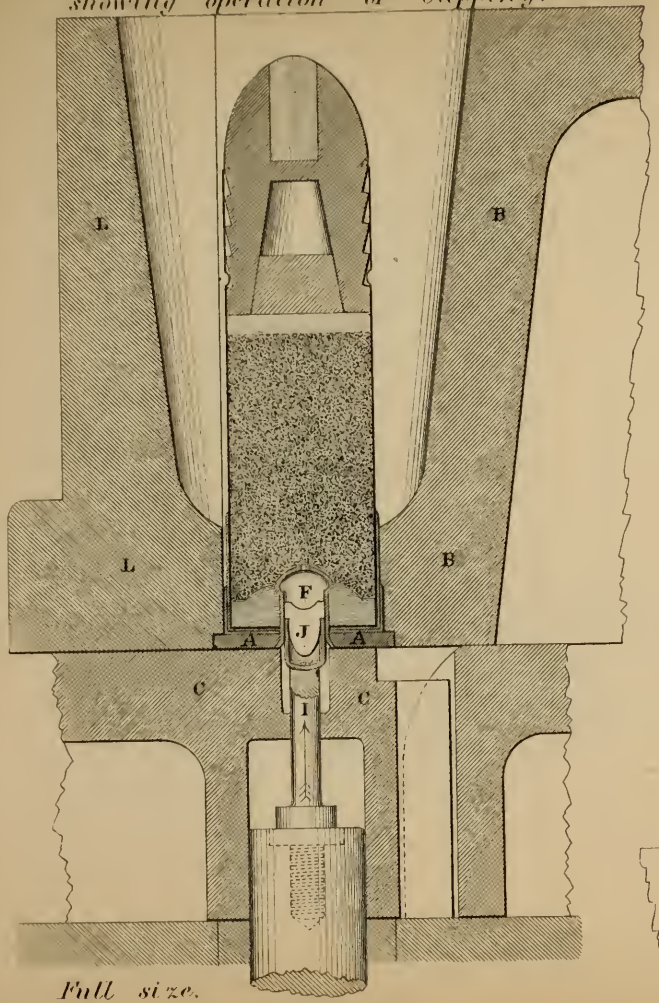
(Proceedings Inst. M. E. 1868.) *Scale 1/8th.*

0 5 10 15 20 25 *Inches.*

CARTRIDGE MACHINERY.

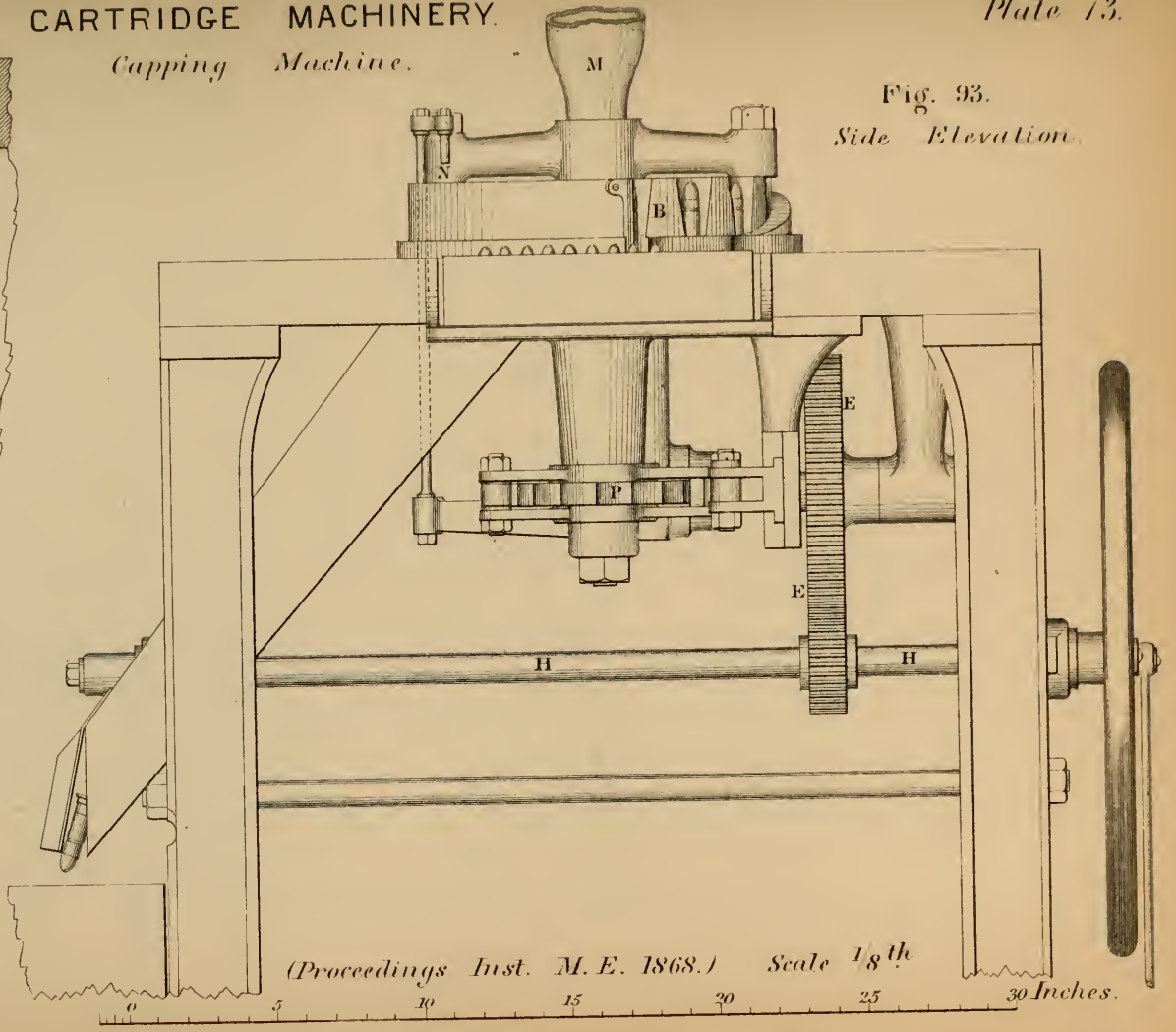
Capping Machine.

Fig. 94. *Full size Vertical Section showing operation of Capping.*



Full size.

Fig. 93.
Side Elevation.



(Proceedings Inst. M. E. 1868.) *Scale 1/8th*

PROCEEDINGS.

28 AND 29 JULY, 1868.

The ANNUAL MEETING of the Members was held at the Philosophical Hall, Leeds, on Tuesday, 28th July, 1868; JOSEPH WHITWORTH, Esq., Past-President, in the Chair.

The Minutes of the last Meeting were read and confirmed.

The CHAIRMAN announced that the Ballot Lists had been opened, and the following New Members were duly elected :—

MEMBERS.

GEORGE EDWARD BELLISS,	Birmingham.
GEORGE BUCKTON,	Leeds.
WILLIAM COCHRANE,	Newcastle-on-Tyne.
JOHN J. DERHAM,	Blackburn.
ALFRED DODMAN,	Lynn.
ROBERT WILLIAM EDDISON,	Leeds.
ARTHUR FIRTH,	Leeds.
JOHN FORSTER,	Barrow-in-Furness.
JOHN JAMES,	Ebbw Vale.
PETER KERR,	Paisley.
JOHN HAWTHORN KITSON,	Leeds.
JOHN LEA,	Bowling.
BENJAMIN MCKAY,	Birmingham.
CHARLES O'CONNOR,	Bath.
ARTHUR PAGET,	Loughborough.
FREDERICK PARKER,	Leeds.
FREDERIC WILLIAM RAFAREL,	Cwmbran.
EDWARD ANTOINE SACRÉ,	London.
GEORGE LAMB SCOTT,	Manchester.

Charles Scriven,	Leeds.
Samuel Taylor,	Leeds.
John Thomson,	Glasgow.
Robert Thornewill,	Burton-on-Trent.
Herbert Wallis,	Bradford.
John Richardson Wigham,	Dublin.
Reginald Wigram,	Leeds.
Lindsay Wood,	Hetton.

ASSOCIATES.

Montague Beale,	London.
Thomas Bright Matthews,	Sheffield.

GRADUATE.

Joseph Hartley Wicksteed,	Leeds.

The following paper was then read:—

DESCRIPTION OF THE MACHINERY FOR THE MANUFACTURE OF THE BOXER CARTRIDGES.

By Mr. THOMAS GREENWOOD, of Leeds.

During the last few years there has been more activity, ingenuity, and competition amongst the inventors and producers of military small arms, than in any other period since the invention of gunpowder. The experience gained during the recent terrible American war does not seem to have been adequately studied in Europe; and it was only when the dire effects were rendered evident of the breech-loading needle-gun, which was so efficiently handled by Prussia in the still more recent German war, that the leading governments of Europe became fully aware of the importance of breech-loading arms. It is true that in this country, shortly before the decisive German battles, it had been determined to change the Enfield rifles into breech-loaders; but no decided steps were taken to carry this resolution into effect. At the present time however every power in Europe is engaged in perfecting and carrying out one or other of the many systems of breech-loaders; and the various merits of the different kinds are criticised with an eagerness which proves the value now attached to the efficiency of this description of arm.

The "magazine rifle," or as it is more commonly called the "repeating rifle," has not yet received the attention it deserves, owing to its more complicated mechanism and the more careful training consequently required by the soldier in order to use it perfectly. The adoption of this rifle however can only be a question of time; for when it is remembered that less than seven years ago the idea of a breech-loader was considered quite impracticable by the leading military men, both in this and other countries, it is evident that only a small amount of further progress is required from the present stand-point of the breech-loader, in order to arrive at

the same conclusions respecting the repeating rifle which have already been attained in regard to the single breech-loader.

But however important it may be to select the best rifle, this question is so bound up with the system of cartridge employed, that the rifle will frequently have to be modified to suit the cartridge. The first attempt to make a breech-loader failed in England, because it was wished to use the same cartridge as that adapted to the muzzle-loader; and it was only when this idea was given up that any real progress was made in perfecting the breech-loader. The attempts to stop the breech of the gun by mechanical means utterly failed, in all cases where the stopper was left exposed to the action of the powder; and this is the most serious defect in the Prussian needle-gun, in which a cartridge case is used made of paper or other self-consuming material. This gun cannot be fired from the shoulder, because the gas escapes at the breech in such a quantity as to injure the eyes of the soldier; and it is therefore fired from the hip, which must seriously interfere with its efficiency in war. The same defect exists also in the chassepot gun, which in principle closely resembles the Prussian needle-gun, especially in some of its worst features, such as having the fulminate powder immediately in the rear of the bullet itself and in front of the gunpowder, and using a paper cartridge, which leaves a residuum in the chamber of the gun; this residuum fouls the mechanism, and consequently impedes its working. With the fulminate in front of the gunpowder, the needle having to pierce through the whole length of the charge of gunpowder before reaching the detonating cap at the front end, is liable to get bent, in which case the point of the needle misses the fulminate, and the result is a miss-fire. The French war department found this defect out after they had contracted for 800,000 chassepot rifles. It is evident therefore that even a first-rate breech-loading rifle will be comparatively worthless, unless the cartridge is equally efficient.

For the Manufacture of Cartridges, simple though they apparently are, numerous ingenious schemes have been devised; and it is only after many failures that anything like a serviceable cartridge has been produced. The requirements of a good cartridge are: first, it must not miss fire; second, it must prevent the escape of any gas

backwards, that is it must be of sufficient strength not to burst with the explosion of the gunpowder; third, the case must be capable of being easily extracted after firing; fourth, it must be to a considerable extent impervious to damp, though not perfectly water-tight; and lastly, it must be of a cheap and light construction.

The system of breech-loading cartridges for military purposes has been divided into two classes, called "rim-fire" and "central-fire." The Rim-fire cartridge, of which an illustration is shown double full size in the sections, Figs. 1 and 2, Plate 30, is generally made out of a copper or brass disc, drawn into the shape of a tube with the rear end closed solid. This end of the tube is then "headed" as it is called, that is the cylindrical part is forced down upon the solid end until a double flange A A is formed, the outside diameter of the flange being about 1-16th inch larger than the diameter of the cylindrical part. The annular cavity inside the flange is filled with fulminate powder, so that a blow upon the outer edge of the flange will close the cavity, and thus cause the fulminate to explode and fire the gunpowder B.

The Central-fire cartridge is best illustrated by the Boxer Cartridge, shown double full size in the sections, Figs. 3 and 4, Plate 30. The case C of the cartridge is made of brass foil rolled into a cylinder and held together by cement, with a lapped joint, the foil making one and a quarter turn; this is covered outside with a wrapping of thin brown paper. The case contains the gunpowder B, with a layer of cotton wool between the powder and the bullet D. The rear of the case is flanged over inwards, and is closed by two cups E made of thin brass, the inner one being twice the length of the outer; and a central hole is punched through the bottom of each cup to receive the cap chamber F, which resembles a hollow rivet with the front end solid. A flange is formed on the rear or open end of the cap chamber, which fits into a countersunk hole in the base disc A; the edge of this disc projects all round beyond the circumference of the cartridge case, so as to form the flange for retaining the case in the gun-chamber when fired. In putting the cartridge together, the cap chamber is threaded through the base disc A and the two brass cups E, and a coil of paper pressed into the form of a thick washer is put inside the case C, surrounding the cap chamber F;

this washer or wad is subjected to a considerable pressure after the parts are put together, and afterwards the solid end of the cap chamber is bulged over or rivetted upon the paper wad; and a small centre hole is punched through the solid end, for the fire of the fulminate to pass to the gunpowder. The anvil J is then inserted into the cap chamber, and the detonating cap G in the rear closes up the open end of the chamber, the fulminate in the cap presenting itself towards the point of the anvil. A blow upon the cap by the firing pin drives it against the point of the anvil and explodes the fulminate; and the fire communicates through the cap chamber to the gunpowder, the anvil J being rectangular in section, as shown in Fig. 4, and thus leaving a clear passage on each side in the cap chamber.

The first machines to be described are for making the Mitford Bullet now used for the Boxer Cartridge, as shown at D in the longitudinal section of the cartridge, Fig. 3, Plate 30. The machine which performs the first operation is shown in Fig. 5, Plate 31. It consists of a heavy bed A A supported on two standards, with two horizontal slides fitted on the front face of the bed and at the opposite ends. The right-hand slide B is moved to and fro by the eccentric C shown dotted, which is supported in a large boss projecting from the back of the bed; and the left-hand slide is actuated by a cam supported in like manner. Both these are driven by pairs of bevil wheels on a shaft passing along the whole length of the machine at the back; on the end of this shaft is a spur wheel D, driven by a pinion on the main driving shaft E. In front of the left-hand slide is mounted a shaft F carrying the circular cutter plate G, which is a plain disc containing twenty holes equally spaced round its circumference. The plate is rotated through the distance of one hole at a time by means of the ratchet-wheel H on the shaft F, which is actuated by a paul worked by an eccentric on the bevil-wheel shaft at the back of the machine. The lead for forming the bullets having previously been drawn into rods of the required diameter, a coil of this drawn lead is placed upon a reel at the left-hand side of the machine; and the lead is drawn into the machine by the traversing gripping apparatus K, which pushes the end of the rod into one of

the holes in the cutter plate G. The next rotation of the plate shears off the length required to form a bullet; and the successive lengths thus sheared being carried round in the holes in the plate are brought successively into line with a horizontal traversing punch I and fixed die, which are similar in general arrangement to those employed in the next machine to be described, as shown in Figs. 9 and 10, Plate 33. The punch is carried on the right-hand slide B, and pushes the blank out of the hole in the plate G into the die on the other side of the plate, where the punch then forms a bell-mouthed recess in the front end of the lead, while it is confined within the die. The bullet is thus moulded to the form shown in the full-size section, Fig. 6; the bell-mouthed recess being in preparation for the cylindrical hole in the front end of the bullet, which receives the wood plug I, Fig. 3. The bullet is then pushed back again out of the die into the hole in the circular plate G, the closed end of the die being moveable and carried upon the left-hand slide of the machine; and the next rotation of the plate brings the bullet opposite the pusher J carried on the slide B, by which it is pushed out of the plate into a delivering spout. The number of bullets produced by this machine in regular work is 60,000 per day of ten hours.

The partially moulded bullets are then taken to the machine shown in Figs. 7 to 12, Plates 32 to 34, which performs the second operation. This machine is of similar construction to the first; but instead of being supplied from the rod lead, the partially formed bullets from the first machine are here fed by hand into the holes of the rotating circular feed plate G, which contains twenty holes, as shown in Fig. 12. The bullets are put into the plate with the front or recessed end foremost, so that the bell-mouthed recess already formed faces the left-hand slide of the machine; and the rotation of the feed plate in the direction shown by the arrow brings each bullet successively into line with the horizontal traversing punch I and fixed die M, shown to a larger scale in the sectional plans, Figs. 9 and 10, Plate 33. The punch I carried by the right-hand slide B pushes the bullet out of the feed plate G into the die M, the closed end of which is made of the required curved shape for the front end of the bullet, so that by the pressure of the punch I the lead is closed around the fixed

centre pin N, which serves as a core for the purpose and is adjusted by lock nuts to the proper length. The original bell-mouthed recess in the front end of the bullet is thus converted into a cylindrical hole for receiving the wood plug; and at the same time the punch I forms the conical recess in the rear of the bullet for receiving the clay plug H, Fig. 3. Round the outer end of the die M a ring of six small holes O O are made, Fig. 10, as a provision against any excess of lead in the die beyond the limit allowed for the weight of the bullet, since it is impossible in the previous operation to cut off with sufficient nicety from the lead rod the exact quantity of metal for the bullet; any surplus therefore exudes through the small holes O O in the die, whereby the bullet is moulded with great accuracy to the exact size and weight required. The fixed centre pin N in the die lies within a hollow sliding rod L, Fig. 10, carried upon the left-hand slide P, Fig. 9; and when the punch I retires on the completion of the bullet, the rod L advances and pushes the bullet out of the die M, back into the feed plate G, by which it is then carried forwards, and afterwards discharged by the pusher J, as shown in Fig. 11. The number of bullets turned out by this machine in regular work is 33,000 per day of ten hours; Fig. 8 shows a full-size section of the bullet as delivered from the machine.

The next operation consists in Canneluring the bullet, or forming four grooves round the cylindrical part of the bullet to hold the lubricating material, as shown in Fig. 3. The Canneluring Machine is shown in Figs. 13 and 14, Plate 35, and consists of a horizontal circular plate A carried on a shaft B, and driven in the direction shown by the arrow in Fig. 13; the plate has a steel rim, the outer edge of which is turned to the exact profile of the grooved bullet. A segment C extending about one fourth of the circumference of the plate A is bolted to the table of the machine, and has its inner edge also turned to the profile of the grooved bullet. The bullets are fed by hand into a spout D and pressed forwards to the bite between the plate and the segment, whence they are rolled round between the two grooved surfaces, which thus form the cannelures or grooves upon them. The finished bullet is shown full size in Fig. 15, and the number of bullets delivered by the canneluring machine in regular

work is 50,000 per day of ten hours. The cylindrical wood plugs in the front end of the bullets are inserted by hand before the canneluring is done, so as to "spin" the lead slightly over the rounded extremity of the wood plug in passing through the canneluring machine; this smoothes the point of the bullet and prevents the plug from falling out. As the clay plugs are not inserted till after the canneluring, the conical hole in the rear of the bullet becomes somewhat contracted in passing through the canneluring machine; but this is provided for by the hole being made proportionately larger in the first instance by the previous bullet-moulding machine.

The machine for making the cylindrical Wood Plugs, which are inserted in the front end of the bullets at I, Fig. 3, is shown in Figs. 16 to 19, Plates 36 and 37. The strip of prepared wood A of square section is carried in the rocking frame B in front of the machine, which is moved inwards and outwards by the cam C. The rotating cutter D, shown full size in Figs. 18 and 19, is carried in a headstock which is moved to and fro by the cam E and lever F; and when the wood rod A is brought into line with the cutter spindle by the rocking frame B, the cutter advances, and cuts the end of the square rod to a cylindrical shape, as shown in Figs. 18 and 20; the central shaper J, Fig. 18, at the same time rounds off the extremity of the rod to the proper curve corresponding with the profile of the front end of the bullet. The cutter then retires; and the rocking frame B being moved inwards by the cam C brings the cylindrical part of the wood rod in contact with the circular saw G, which cuts off the plug to the required length, and it falls into a drawer beneath. The wood rod A is held in a sliding gripper H, having a paul that catches in the feeding rack K, the teeth of which are spaced to the exact length of the wood plugs; and when the rocking frame B is pushed outwards by the cam C, the rack K is advanced the space of one tooth by means of a projecting stud underneath the rack, bearing against the inclined plane L, shown dotted in Fig. 17, which is attached to the table of the machine. The wood rod is thus fed forwards towards the cutter to the required length for the next plug; and when the rocking frame B next moves inwards

towards the circular saw, the feed rack K is pushed backwards by the spiral spring N, so that the paul on the gripper H drops into the next tooth of the rack. The cutter spindle D and circular saw G are each driven by belts from the main driving shaft M, from which the cam shaft is driven by gearing O. The wood plugs are turned out by the machine at the rate of 15,000 per day of ten hours in regular work; and are inserted by hand into the front end of the bullets previous to the canneluring. The wood used for making the plugs is sycamore or beech; and the wood rods are soaked in cold-drawn linseed oil, chiefly in order to make them cut more easily.

The Clay-Plug Making Machine, shown in Figs. 21 to 25, Plates 38 to 40, moulds the clay plugs which are put into the conical recess H, Fig. 3, in the rear of the bullets, for the purpose of expanding this part of the bullet at the moment of firing, so as to force the lead into the grooves of the rifle barrel. The clay plugs are made from dry clay previously ground to a fine powder, which is compressed to the required shape in a mould by means of the vertical pressing slide A, Fig. 21; a heavy pressure is put upon the slide by the strong lever B, actuated by the cam C on the main cam shaft D. The cam is faced with steel at the part where the greatest pressure takes place; and works against an adjustable hinged flap, also faced with hardened steel, on the underside of the lever B. The bottom of the pressing slide A has a round head carrying fifty steel pins, as shown to a larger scale in Fig. 25, which compress the powdered clay in a corresponding number of moulds. Five sets of these moulds are let into a circular rotating table E, Fig. 23, which is mounted in the front of the machine, as shown in Fig. 21; and each set of moulds in succession is brought round under the pressing slide A by the intermittent rotation of the table, which is turned by means of the ratchet wheel F, Fig. 22, actuated from the cam shaft D. The bottoms of the fifty moulds in each set are closed by a corresponding number of steel pistons, the lower ends of which rest upon the circular block G, Figs. 24 and 25; this block is itself a piston fitting into the recess in the moulding table, and when brought round under the pressing slide A it rests upon the large vertical screw K carried in the frame of the machine,

so that the pressure put upon the moulds by the slide A is borne by the screw K, instead of coming upon the moulding table E. In order to land each mould in succession upon the top of the screw K, the moulding table is lifted slightly at each time of turning by means of a spiral incline or crown ratchet-face I, Fig. 21, fixed to the centre spindle on the underside of the table; this incline raises the table $\frac{1}{4}$ inch, which gives the bottom of the mould 1-8th inch clearance above the top of the screw, and as soon as the mould is brought over the screw the table drops again $\frac{1}{4}$ inch, leaving the bottom of the mould resting solely upon the screw. The prepared clay for making the plugs is supplied from the brass hopper L through the pipe M, Fig. 24, which is closed by a flap valve at the bottom; a tappet J, Fig. 25, fixed on the pressing slide A, catches the valve lever N in each upstroke of the slide, and opens the valve, allowing a sufficient quantity of the clay for one set of fifty plugs to fall into the feed box P, in which it is distributed uniformly by the revolving arms Q. The bottom of the feed box is closed by two plates, perforated with fifty holes each, between which is a sliding plate R, also containing fifty holes, and worked by a cam on the main cam shaft. The holes in the bottom plate correspond exactly with the moulds in the moulding table, while those in the top plate are all set back a certain distance so as not to be opposite the holes in the bottom plate; and the sliding plate R is made of such a thickness as to measure off in each hole the exact quantity of clay required for each mould. The clay falls first out of the feed box into the measuring plate, and the plate being then moved forwards by the cam shuts off the communication with the upper holes, and allows the charge to drop through the lower holes into the moulds beneath, as shown in Fig. 24. The charged moulds are then brought round under the pressing slide A and subjected to the pressure; after which the next stroke of the machine and rotation of the cam shaft lifts up the block G supporting the steel pistons in the bottom of the moulds, Fig. 24, and pushes out the newly moulded plugs to a level with the surface of the moulding table E; this is done by means of the vertical plunger T, worked by the levers S S, Fig. 21, which are actuated by a face cam on the outer end of the cam shaft D. The swivelling

arm U, Fig. 23, actuated by another cam W, then sweeps the plugs off the table E; and the same lever that works the swivelling arm withdraws at the same time the locking bolt V, which is provided for stopping the table dead after each turn and for holding it perfectly steady during the time that the clay is being compressed in the moulds under the pressing slide. A self-acting oiling apparatus is mounted over the moulding table at X, Fig. 21, so as to oil each set of moulds by a corresponding set of fifty vertical plugs, which are passed down into the holes as they come under, the plugs being covered with cloth kept moistened with oil. The machine moulds the plugs at the rate of 150,000 per day of ten hours, each revolution of the cam shaft producing 50 plugs, as shown full size in Fig. 26; the plugs are subsequently baked in an ordinary oven.

The next machine, shown in Figs. 27 to 33, Plates 41 to 43, is for Warming the bullet and Pressing in the conical clay plug H, Fig. 3, in the rear of the bullet. The object of heating the bullet is to expand it slightly, and thus fix the clay plug more firmly by the contraction of the bullet in cooling. The heating is effected by means of a horizontal steam wheel A, driven at the rate of rather less than one revolution per minute by a worm upon the cam shaft B, and supplied with steam through two of its hollow arms, the other two serving as waste pipes for the escape of the condensed water. The wheel has eighty brass cups fitted into its upper face, as shown in the plan, Fig. 27, into which the bullets are inserted by hand with the rear end uppermost. The bullets are fed in on the right-hand side of the machine at C, Fig. 27, the wheel revolving in the direction of the arrow, and by the time they reach the opposite side of the machine at D another attendant inserts the clay plug; after which they are removed from the wheel by hand and inserted into the holes in the circular feed plate G. This plate, containing twenty holes, Fig. 29, is rotated one hole at a time by a ratchet wheel and paul actuated by an eccentric E on the end of the cam shaft B; and it brings each bullet in succession into line with the two horizontal plungers I and J, Fig. 30, as shown to a larger scale in Fig. 31, Plate 43. These plungers are worked to and fro by levers actuated by the cams K and L on the shaft B, Fig. 27; the right-hand

plunger I pushes the bullet out of the feed plate G into the fixed die M, which is bored out to the exact diameter of the rifle barrel, and acts as a gauge, preventing the bullet from being expanded by the pressing in of the conical clay plug. The left-hand plunger J advancing at the same time, as shown in Fig. 32, holds up the bullet against the plunger I with a definite amount of resistance, by means of the bell-crank lever F weighted by the spiral spring N, Fig. 30; the clay plug is thus pressed home into the rear of the bullet with a uniform pressure which cannot exceed the limit determined by the spiral spring. The left-hand plunger J, the head of which is recessed to receive the front end of the bullet, is now suddenly withdrawn by its cam, as shown in Fig. 33, and the bullet being pushed out of the gauge M by the plunger I falls into the delivering spout P, a small striker-off O being provided to ensure its falling clear. A full-size section of the finished bullet is shown in Fig. 28, and the number delivered by the machine is 40,000 per day of ten hours.

The foregoing machines, shown in Plates 31 to 43, complete the series of operations required for the production of the Bullets; and the next machines to be described are those for the manufacture of the several parts composing the Cases of the cartridges.

The Base-Disc Punching Machine, shown in Figs. 34 to 36, Plates 44 and 45, is for the purpose of making the base-disc A, Fig. 3, Plate 30, which closes the rear end of the cartridge, and forms the projecting flange all round for withdrawing the empty cartridge case from the rifle chamber after firing. Four of these base discs, one of which is shown full size in Fig. 37, are punched simultaneously at each stroke of the machine, out of a long thin strip of iron B B, Figs. 35 and 36, by the four hollow punches C carried on the left-hand slide D, which is set at an inclination, so as to punch the four discs diagonally out of the iron strip B, as seen in Fig. 35. Each punch works into a fixed bolster E, within which is a smaller punch F carried by the right-hand slide G; and as soon as the disc is punched out of the strip B, Fig. 36, the smaller punch F advances and punches out the centre hole in the disc, the hollow punch C serving as the bolster to the smaller punch F. As the

two punches recede from each other, the smaller one carries back the disc with it, until it is stripped off by coming against the bush H through which the punch F works. A vertical plunger I, actuated by the cam K, then pushes the disc down, and it is discharged by the delivery spout L. The centre burrs punched out of the discs are discharged through the interior of the hollow punches C into the spout M. The iron strip B out of which the discs are punched is ·05 inch thick, and is traversed through the machine by the two pairs of feeding rollers N N, Fig. 35, each pair being driven with the required intermittent motion by means of a ratchet wheel and paul worked from the eccentric P. The machine makes 85 strokes per minute, and produces an average number of 136,000 base discs per day of ten hours.

The Base-Disc Countersinking Machine, shown in Figs. 38 and 39, Plates 46 and 47, is for the purpose of countersinking the centre hole in each disc, as shown full size in Fig. 40. The discs are fed by hand into the holes in the horizontal circular feeding table B containing twenty holes, by which they are carried round and brought successively underneath the countersink drill I; the drill spindle is driven by a strap from the vertical shaft C geared with the main driving shaft D. The drill spindle is mounted in a vertical slide E, which has a short vertical movement imparted to it from the eccentric F through the bell-crank lever G, so as to bring the drill down upon each disc successively coming under it. At the same time the hollow bolster J, carried in a lower vertical slide, is raised by means of the cam H and lever K, and presses the disc up against a small fixed stop, placed level with the upper side of the feed table B; the disc is thus gripped firmly and held secure from turning during the time that the drill is making the countersink. At the next move of the table B a plunger carried on the upper slide E pushes the countersunk disc down through the hole in the table, and it is discharged through a delivery spout. The feed table B is rotated by the ratchet-wheel and paul L, Fig. 38, actuated by the lever M and grooved cam N, Fig. 39; and the table is steadied in each stationary position by the weighted catch P fitting into notches in the circumference of the table. The machine countersinks the

discs at the average rate of 24,000 per day of ten hours in regular work.

The Base-Cup Making Machine, shown in Figs. 41 to 45, Plates 48 to 50, is for the purpose of making the deeper of the two base-cups E, Fig. 3, which with the base-disc close the rear end of the cartridge. This machine is similar in general arrangement to the base-disc punching machine already described, and punches four circular discs simultaneously out of the thin strip of brass B by means of the four hollow punches C carried in the left-hand diagonal slide D, which is driven by the cam R, Fig. 44. The fixed bolsters E, Fig. 45, against which the punches C work, contain each a sliding socket S, which is pressed forwards against the punch C by a strong spiral spring H, set up by the hollow tail-screw T; so that the flat disc of brass punched out of the strip B is gripped tight all round the circumference between the punch C and the socket S. Whilst the disc is thus held during the dwell or stationary part of the cam R, the right-hand slide G advances the mandril F within the hollow socket S; the end of the mandril has its edge slightly rounded, and presses the disc into the hole in the hollow punch C, the aperture of which is made slightly bell-mouthed, so that the flat disc may be gradually drawn into the shape of a cup as it passes forwards into the cylindrical part of the hole. The finished cups are pushed forwards through the hollow punch by each successive cup as it is formed, and are discharged through the delivery spout M, Fig. 41. The machine shown in the drawings produces the deeper of the two base cups, as shown full size in Fig. 43; and the shallow base cup, which fits outside the deep one, is made by another machine of exactly similar construction, the only difference being in the sizes of the punches, &c. The inner cups are made of very thin metal, the brass strips out of which they are punched being only ·005 inch thick; but the outer cups are rather stronger, being made out of brass strips ·007 inch thick. Each base-cup machine is driven at 60 strokes per minute, making four cups at each stroke, and produces on the average 136,000 base cups per day of ten hours. The outer cup is made to be rather a tight fit upon the inner, and is pressed over it by hand;

after which, by means of the small Hand Lever Press shown in Figs. 46 and 47, Plate 51, a centre hole is punched in the base of each pair of cups, to receive the cap chamber F, Fig. 3; the punching is done at the rate of 12,000 per day of ten hours.

The Cap-Chamber Punching Machine, shown in Figs. 48 to 53, Plates 52 to 54, punches flat circular discs out of a long strip of brass, and then bulges each into the shape of a cylindrical cup, for the purpose of forming the cap chamber F in the rear of the cartridge, Fig. 3. This machine is very similar to the one already described for making the base cups, the principal difference being that the cap chambers are of smaller dimensions than the base cups, and consequently require less power for making them. The slides carrying the four pairs of hollow punches and mandrils are here placed horizontal, while the strip of brass B is fed through the machine at an inclination, as shown in Fig. 49. The shape of the bell-mouthed aperture in the hollow punch, and the rounded end of the mandril, are shown full size in Figs. 51 and 52; but as the thickness of the brass strip is ·02 inch, and the length of the finished cap chamber is about twice as great as its diameter, it is not attempted to produce the full length of cup out of the original flat disc at a single operation; the cap chamber is therefore made by this machine of the shape shown full size in Fig. 50, and afterwards undergoes a further drawing process in the machine next to be described. The cap-chamber punching machine is driven at 90 strokes per minute, and produces in regular work the average number of 144,000 cap chambers per day of ten hours.

The Cap-Chamber Drawing Machine, shown in Figs. 54 to 56, Plates 55 and 56, is for drawing out or elongating the cap chambers delivered from the preceding machine. The vertical slide A, worked up and down by a crank and connecting-rod from the shaft B, carries at the bottom a pair of rounded mandrils or punches C working into the very taper bolsters D, as shown full size in Fig. 56. A horizontal slide J underneath the punches C is moved backwards and forwards by the weight E and the face cam F on the crank shaft B; this slide carries two spring grippers, having

recesses to receive the cups, which are fed by hand into two bell-mouthed holes in a tray H fixed in front of the punches. The sliding grippers carry a pair of the cups underneath the punches, which then descend and force the cups through the taper bolsters, thus elongating them by a drawing action. The cups are stripped off the punches in the up stroke, and the grippers at the same time return and bring up a fresh pair of cups for the punches. The machine makes 55 strokes per minute, delivering 50,000 cups per day of ten hours in regular work. The cups or cap chambers delivered from this machine, as shown full size in Fig. 57, are then annealed, and afterwards subjected to a second drawing process in a similar machine, by which they are finally elongated to the required extent.

The Cap-Chamber Trimming Machine, shown in Figs. 58 to 61, Plates 57 and 58, is for the purpose of trimming off to the exact length the open end of the cap chamber after the final drawing process. The cups to be trimmed are fed by hand into the holes in the circular feeding plate A containing fifteen holes, by which they are successively brought round into line with the horizontal sliding stud B and revolving chuck C. The slide D carrying the stud B is worked to and fro by the eccentric E, driven by belt and gearing from the main driving shaft F; and the stud entering the cap chamber pushes it into the gripping chuck C, as shown full size in the sectional plan, Fig. 61. The chuck is driven by a belt G from the driving shaft F, and runs at 5760 revolutions per minute, carrying the cap chamber with it. The trimming knife or cutter J, mounted on an oblique slide K, is then moved forwards by a cam on the back end of the shaft of the eccentric E, and trims the outer end of the cap chamber to the exact length required. The slide K is placed at an inclination of 45° to the axis of the chuck, as shown in the plan, Fig. 60, so as to cut the edge of the cap chamber with an internal bevil at that angle, as shown full size in Fig. 59, for the purpose of facilitating the flanging of the edge in the next process. When the trimming is completed, the cutter J and stud B are withdrawn; and the cap chamber being pushed out of the chuck C by the plunger L, sliding within the hollow spindle of the chuck,

falls into a box beneath. The plunger L is attached to the slide D by the rod M, Fig. 58, so that the stud B is withdrawn clear out of the cap chamber, before the plunger L begins to push the cap chamber out of the chuck C. The circular feeding plate A is rotated one hole at a time by means of the paul and ratchet-wheel N, worked from the cam P, Fig. 60, on the front end of the shaft of the eccentric. The machine trims the cap chambers at the rate of 30,000 per day of ten hours in regular work.

The Cap-Chamber Flanging Machine, shown in Figs. 62 to 65, Plates 59 and 60, completes the cap chambers by "hatting" them or flanging the edge over outwards, forming the flanged rim which fits into the countersink in the base disc A, Fig. 3. The pair of flanging punches JJ, Fig. 64, carried in the vertical slide B, press the cap chambers into the fixed dies C C underneath; and the open end of the cap chamber projecting above the top edge of the die is flanged over outwards all round by the punch, as shown full size in Figs. 63 and 65. The flanging is facilitated by the internal bevil given to the edge of the cap chamber in the previous trimming process; and the shoulder of the punch J, Fig. 65, is rounded out to the shape of the required flange, while the edge of the die C is left square, as shown, without any rounding off. The bottom of the die has a small hole through it, which is closed by the vertical plunger I resting by a collar upon a fixed stop D below, Figs. 62 and 64; the top of the plunger is slightly hollowed out, so as to complete the bottom of the die to the correct shape for receiving the cap chamber, as shown in Fig. 65. When the punch J rises after flanging the rim of the cap chamber, the plunger I is lifted by the slide B through the lever E, and raises the flanged cap chamber to the level of the top of the die, as shown dotted in Fig. 65. The pair of finished cap chambers are then swept off sideways, right and left, into the receptacles F F, Fig. 64, by the two horizontal arms G, which are carried on the bottom of the two vertical shafts H and actuated by the face cam K, Fig. 62. The slide B carrying the punches J is worked by a crank on the extremity of the cam shaft. The cap chambers to be flanged are fed into the machine by hand through a pair of holes in the feeding tray L, and are carried

forwards to the dies by spring grippers on the sliding bar M, which is worked by the second cam N, exactly the same as in the cap-chamber drawing machine previously described. The flanging of the cap chambers is performed by the machine at the rate of 44,000 per day of ten hours in regular work.

The Paper-Wad Making Machine, shown in Figs. 66 to 69, Plates 61 and 62, produces the paper wads, which are pressed into the bottom of the cartridges, Fig. 3, for the purpose of holding the various parts together. The wads are made out of long narrow strips of paper, wound in a coil upon a small revolving mandril A, Fig. 66; the width of the strips is equal to the thickness of the wad, and their length such that each strip makes a complete cylindrical wad of the required diameter, as shown full size in Fig. 67. The mandril A has a slit in it, into which the end of the paper strip is inserted; and the mandril being then made to revolve, winds up a coil of paper upon itself, as shown in Fig. 68, the paper strip being guided upon the coil by hand; the outer end of the paper is first pasted to prevent the wad uncoiling when finished. Each successive layer is pressed solid upon the previous one by the constant upward pressure of the pressing roller B, which is carried upon the top of the rod C, and held up against the paper coil by the india-rubber spring D. The mandril A is fixed in the front end of the spindle E, and the back end of this spindle carries an internal pulley F, within which runs a friction pulley G covered with hard leather, and driven by a belt from the main driving shaft H of the machine. The spindle of the friction pulley G is mounted in a rocking headstock J, connected by the rod K with the treadle L; and a spiral spring M underneath the treadle holds the headstock J in the central position, so that the friction pulley G is not in contact with the internal pulley F on the mandril spindle. For winding the wads, the friction pulley G is pressed against the internal pulley F by the treadle L. When the coil is completed, the pressing roller B is lowered by the second treadle N; and the same movement withdraws the mandril A by means of the double bell-crank lever P, the lower ends of which pass through two slots in the headstock of the mandril

spindle E, and work in an annular groove in the spindle itself, Fig. 66; the newly wound wad is thus stripped off the mandril. The average number of wads made by the machine in regular work is 5,500 per day of ten hours.

The Paper-Wad Pressing Machine, shown in Figs. 70 to 74, Plates 63 to 65, is for the purpose of subjecting the paper wads to a severe pressure, so as to consolidate them throughout and compress them each to exactly the same thickness. The wads delivered from the preceding machine are fed by hand into the sixteen holes in the horizontal circular feed plate A, which brings each wad in succession under the pressing punch B, Fig. 70, carried in the vertical slide C, which is driven by a connecting-rod from the crank shaft D. The descent of the punch pushes the wad out of the feed plate A into the die E underneath, as shown full size in the vertical section, Fig. 74; and by the pressure of the punch the wad is compressed while in the die, and reduced to the exact thickness required, which is determined by the adjustment of the length of the punch. The hole in the centre of the wad fits upon the pin or mandril I, fixed in the centre of the die, which preserves the full size of the hole during the pressing. The bottom of the die is closed by a tubular slide G carried upon the crosshead H, Fig. 71; and under the pressure of the punch this slide is supported by a collar resting upon the bracket K cast on the frame of the machine, Fig. 70. In the ascent of the punch after pressing the wad, the pair of side rods L L, Fig. 71, from the vertical slide C to the crosshead H, raise the tubular slide G, which pushes the finished wad out of the die E back into the feed plate A; at the next stroke of the machine the wad is discharged from the feed plate by the stud N carried on the slide C, Fig. 71. The rotation of the feed plate A is effected by the star wheel M, Figs. 72 and 73, driven by gearing from the crank shaft D. The machine makes 75 strokes per minute; and the finished wads, one of which is shown full size in Fig. 75, are delivered at the rate of 30,000 per day of ten hours in regular work.

The next operation consists in Putting together by hand the several parts forming the body of the cartridge, and fixing them

partially by means of the Hand Lever Press shown in Figs. 76 and 77, Plate 66, previous to the final compression given by the fixing machine shown in Figs. 81 to 84, Plates 67 to 69. The paper wad is put in the rear or closed end of the cartridge case, which is then covered by the two base cups and the base disc; and the cap chamber being inserted through the centre hole, all the parts are then pressed home upon one another in the hand lever press, Figs. 76 and 77, which has a horizontal sliding plunger A, working against a fixed bolster B, and moved by the hand lever C. The face of the plunger is recessed, so as to bear upon the base disc of the cartridge all round the circumference only; and in the centre of the plunger is a small projecting stud or mandril, fitting exactly inside the cap chamber, which is thereby pressed in through the centre hole in the paper wad; and the bolster B is made hollow, with a centre hole of the same diameter as that in the wad. With this press the cartridge bodies are put together at the rate of 3,000 per day of ten hours in regular work.

The Fixing Machine, shown in Figs. 81 to 84, Plates 67 to 69, completes the operation of fixing the body of the cartridge securely together, by subjecting the paper wad to a heavy pressure, so as to make it fit tight round the cap chamber and in the end of the cartridge case, and fix the cylindrical cartridge case securely in the base cups. The cartridge bodies already partially fixed are fed by hand into the notches in the circumference of the circular feed table A, whereby they are brought round successively under the pressing plunger B carried in the vertical slide C, which is driven by a connecting-rod from the crank shaft D. The plunger is made hollow, with the bottom face recessed, as shown full size in Fig. 84, so that it presses first all round the circumference of the paper wad K, closing it in tight upon the cap chamber F, and bulging it upwards in the centre round the cap chamber, as shown in Fig. 84. In order to prevent the cartridge case and base cups from being bulged outwards by the pressure of the plunger upon the paper wad, the semicircular notches in the feed table A are shaped exactly to the external profile of the cartridges; and as each cartridge is brought round under the plunger, a corresponding semicircular swage or

die on the end of the horizontal slide E is advanced by means of the face cam G on the crank shaft D. The cartridge is thus securely embraced all round in a closely fitting die during the time that it is under the pressure of the plunger. The horizontal pressure of the slide E against the feed table A is received by a brass bearing on the opposite side of the feed table, set up by the screw H. The feed table is rotated by the star wheel L, Fig. 81; and the cartridges after being fixed are discharged from it by the curved finger J, Fig. 83, which lies in the groove M, Fig. 84, turned in the circumference of the feed table. The machine makes 55 strokes per minute, and turns out the cartridges at the rate of 30,000 per day of ten hours in regular work.

The Cap-Chamber Rivetting and Piercing Machine, shown in Figs. 85 to 90, Plates 70 and 71, rivets the closed end of the cap chamber over the paper wad, and then pierces the firing hole through the cap chamber. The cartridge cases are fed by hand, rear end upmost, upon the upright studs I I on the circular feed table A, by which they are brought round in succession under the rivetting punch B, Figs. 88 and 89, carried in the vertical slide C. The punch B is made with a projecting pin at the bottom, as shown full size in Fig. 89, exactly fitting the cap chamber F, so as to prevent the cap chamber from buckling inwards under the pressure of the punch in the rivetting; and the pressure of the punch B is distributed over the whole area of the base disc of the cartridge by the small plate D, supported by two bolts with india-rubber washers E, which yield to the pressure of the punch. The top of each stud I is recessed to the required shape, and serves as the die in which the closed end of the cap chamber is rivetted over the paper wad by the pressure of the punch; by this means the paper wad, cartridge case, base cups, and base disc, are all held securely together by the cap chamber in the centre, the open end of the cap chamber being countersunk into the base disc, while the closed end is rivetted over the paper wad. A projecting stud G fixed on the side of the slide C, Fig. 88, presses each cartridge case down home upon its die before it comes under the rivetting punch B. After the rivetting, the next turn of the feed table A brings the cartridge under the piercing needle J, shown

full size in Fig. 90, which is also carried in the vertical slide C; the stud I is made hollow in the centre to receive the point of the needle, Fig. 90, which pierces the small hole through the rivetted end of the cap chamber, for the fire from the fulminate in the cap chamber to communicate with the gunpowder in the cartridge case. Full-size sections of the cartridge case are shown in Figs. 86 and 87, before the rivetting, and after rivetting and piercing. The cartridges are removed by hand from the studs on the feed table; and the machine makes 65 strokes per minute, delivering the cartridges at the rate of 37,500 per day of ten hours in regular work.

The cartridge case is then filled with the required charge of gunpowder, covered with a small wad of cotton wool in front, as shown in Fig. 3; after which the bullet is inserted in the open end of the cartridge case, and secured by indenting the case all round into the lowest groove or cannelure in the bullet. This is done by the Choking Apparatus shown in Figs. 78 to 80, Plate 66, having a pair of semicircular dies, closed upon the cartridge by a hand lever; two strokes of the press are given for fixing the bullet, the cartridge being turned a quarter round between the strokes, so as to secure the bullet completely all round. The operation is performed at the rate of 5,500 cartridges per day of ten hours in regular work with a single choking press.

The Capping Machine, shown in Figs. 91 to 94, Plates 72 and 73, is the last of the machines employed in the manufacture of the cartridges, and performs the final operation of inserting and pushing home the detonating cap G and the anvil J, Fig. 3, in the cap chamber F. As this has to be done after the cartridge is loaded with the powder and ball and the cap charged with fulminate, it is necessarily a dangerous process; until recently it was performed by hand, but in consequence of a fatal accident the machine shown in the drawings was invented, which to a very great extent obviates all risk. The machine has two circular feeding tables B and C, Figs. 91 and 92, geared together by equal spur wheels. The larger table B has fifteen recesses in its circumference to receive the charged cartridges, which are fed upright into the recesses with the

base downwards; the rim of this table projects over that of the smaller table C, which contains fifteen holes to receive the detonating caps and anvils fed in by hand. By the rotation of the two feed tables the cap is brought round exactly underneath the cartridge, on the centre line of the two tables, as shown full size in Fig. 94; and the vertical plunger I then pushes the cap and anvil up into the cap chamber F of the cartridge. The plunger I is carried in a vertical slide D actuated by a crank on the shaft of the spur wheel E, Fig. 92, which is driven by a pinion on the main driving shaft H, worked by the treadle K. The cartridge is held down against the upward pressure of the ascending plunger I by the shoulder on the table B and the fixed crossbar L, projecting over the edge of the base disc A, Fig. 94. Immediately over the cartridge where the cap is being inserted is fixed a vertical brass tube M, about 3 inches diameter; so that in case of the cartridge exploding, the bullet and the gas from the explosion are discharged up the tube, thus protecting the attendants from danger. The finished cartridges are pushed out of the feed table B by the plunger N, Fig. 93, carried on the same vertical slide D as the capping plunger I. The two feed tables are rotated by the ratchet-wheel P, which is worked from a cam formed in the side of the spur wheel E. By this machine the capping of the cartridges is done at the rate of 20,000 per day of ten hours in regular work.

The entire set of twenty-one machines that have now been described in their regular order of succession are all employed in the manufacture of each cartridge; and the several operations required are performed by the machines at the very rapid rates of from 3,000 to 150,000 per day, as named for each machine.

Mr. GREENWOOD exhibited a series of separate specimens of the several parts forming the complete cartridge, in illustration of the successive stages of the manufacture.

Mr. W. E. NEWTON remarked that the great variety of machines described in the paper just read displayed a large amount of ingenuity in adapting their construction to the numerous operations required to be performed in the manufacture of the cartridges; and he was sure the meeting must congratulate the author of the paper upon the mechanical ability which had been manifested in working out so difficult a problem with such thorough success. With regard to the relative advantages of the rim-fire and central-fire cartridges, the former had certainly the merit of greater simplicity, as seen by a comparison of the two kinds of cartridge shown in the drawings. At the same time however he thought the rim-fire cartridge had some serious disadvantages, the principal of which was that the fulminate was placed within the groove which formed the flange round the rear end of the cartridge; and in the formation of this projecting flange out of the original cylindrical cartridge case, the metal became so much attenuated, that the rim itself was liable to be burst by the explosion of the fulminate in firing, and cause injury to the eyes in firing the rifle. Another objection was that it was necessary to fill the rim with fulminate all round the entire circumference, thereby using eight or ten times as much fulminate as was really needed to fire the gunpowder, and at the same time increasing the risk of bursting the rim itself and letting out a back-fire. In the plan of central-fire cartridge described in the paper he did not see what advantage was gained over the ordinary metallic cartridges, which were made so completely impervious to water that they might be kept under water for almost any length of time, and would yet be preserved perfectly dry and ready for firing at any moment. The cartridge case shown in the drawing however, not being perfectly water-tight, there would at any rate be great risk in putting it into water; and if it did accidentally get wet, the chances were certainly against its exploding. For although the cylindrical part of the case containing the gunpowder was made with a thin film of metallic coating underneath the external paper

covering, it was not made sufficiently secure at the joints of the metal to exclude moisture. That construction might no doubt be a little lighter and less expensive in the manufacture, owing to the use of the thin brass foil, instead of the thicker metal case employed in the ordinary metallic cartridge; but he did not think this would counterbalance the great disadvantage of its not being perfectly waterproof. The objections felt to the use of metallic cartridges when breech-loaders were first generally adopted, from the idea that there was danger of the cartridges exploding by being knocked about before they were put into the gun, had proved altogether unfounded, as it had been shown that they might even be hammered under a sledge hammer without risk of exploding; and these cartridges had been used with very good results in the United States and other countries. In England it had been decided to convert the Snider rifle so as to adapt it for a central-fire cartridge; but he did not think that construction of breech-loader was good enough to be the one ultimately used in this country, and it could only be regarded as a temporary expedient. Other countries had experienced similar difficulties in arriving at a satisfactory construction of breech-loader, the Prussian needle-gun having been found extremely defective; while the French chassepot rifle, also a needle-gun, had proved very little better, although possessing some points of merit. The liability however of the needle-gun to miss fire frequently, on account of the long needle getting slightly bent, as explained in the paper, was a most serious objection, which unfortunately had not been recognised by the French military authorities until after a very large supply of these breech-loaders had been procured; and in consequence of this defect the chassepot gun he believed was now about to be abandoned.

Mr. Greenwood said he had not intended to enter at all into the question of which was the best cartridge, and he thought that was a very debatable subject; but his object had been simply to describe the machinery employed in the manufacture of the one particular construction of central-fire cartridge which was required to be produced in such large numbers, for the supply of the army of this country. With regard to the invention of the machinery for this purpose, he wished to mention that a large share of the merit of

designing it was due to Mr. Davidson, of Woolwich Arsenal, who had been working at the subject for a great length of time; and it had only been step by step that they had succeeded in arriving at the present state of perfection in the manufacture of the cartridges.

The CHAIRMAN enquired what was the rate at which the cartridges were now being produced by the machinery described in the paper.

Mr. J. DAVIDSON replied that the cartridges were being produced at the rate of $1\frac{1}{4}$ millions per week in regular work at the manufactory in Woolwich Arsenal.

The CHAIRMAN enquired what had been the principal mechanical difficulties met with in designing the numerous machines employed for manufacturing the cartridges.

Mr. GREENWOOD said that the difficulties arose gradually during the experiments upon the successive constructions of cartridge that were tried before arriving at the one now adopted. The most serious difficulty had been to make the base or rear of the cartridge case sufficiently strong to resist the explosion of the powder; and it had been originally attempted to close it with only a single base cup, having an external projecting rim formed round the base by a process called "heading," like the hollow flange of the rim-fire cartridge, this rim being for the purpose of getting hold of the empty cartridge case for extracting it after firing. But it was soon found that this construction had the same defect which had been pointed out in reference to the rim-fire cartridge, the metal being made so much too thin at the angle by the stretching in flanging over that it was liable to be burst round the edge by the explosion. The two base cups, the deeper within the shallower one, were therefore adopted to strengthen the rear of the cartridge; and it was the production of these base cups in large quantities out of the very thin metal employed for the purpose which had been found one of the greatest of the mechanical difficulties to be overcome. The machine for making the cups had four hollow punches and bolsters for punching circular discs out of the flat sheet of thin metal; and a mandril working within the bolster then forced the disc through a bell-mouthed aperture in the hollow punch, so as to draw the flat disc into the shape of the cylindrical base-cup. In

the first attempts to accomplish this, the edges of the cups were found to be puckered all round; and it was only after a great number of attempts had been made and several months spent in experimenting that it was ascertained that the puckering arose from the mandril and the hole inside the punch not being made with sufficient accuracy to work well together; but now that they were made perfectly accurate, the machine worked quite well, and no difficulty was experienced in making the cups without any puckering.

Mr. W. Bouch enquired whether the success was at all due to the use of any particular material for the metal cups or for the mandrils.

Mr. Greenwood replied that the absence of puckering did not depend upon the metal used for the cups, but upon making an exact fit between the mandril and the cylindrical hole in which the metal was drawn into a cup; and an error of 1-1000th inch in the diameter of either the mandril or the hole was enough to spoil the cups turned out. Each machine was made with four punches, for the purpose of producing the cups with the required rapidity, and there was no means of adjusting each pair of punches and bolsters separately; the great difficulty therefore lay, first in getting the slides fitted and bedded so accurately that they would work a considerable time without any perceptible wear: and then in boring out the holes to receive the punches, bolsters, and mandrils, with such perfect accuracy that when these several parts were each ground up to the standard gauge, and fitted into the holes in the slides, they would work together with complete truth, without any other adjustment. When this was once accomplished, the machine would continue afterwards to work with entire success. The mandrils were made of steel, and the machine was tried beforehand by setting it to punch the thinnest tin foil, such as was used for covering the necks of bottles; and if it was successful in forming perfect cups out of this, it was considered correct and fit for use for the manufacture of the cartridge base-cups; the thinnest paper was not considered to give a sufficiently severe test, and the tin foil was therefore used instead for testing the accuracy of the machine.

Mr. H. Chapman observed, in reference to the difficulty of making the base cups without puckering, that the metal capsules manufactured for containing moist colours were made without puckering, and he understood they were made by simply raising the disc of metal by the pressure of a punch in a shallow die, without the necessity of employing a die of the full depth of the capsule: for instance, a capsule 2 inches long could be made with a die of only $\frac{1}{4}$ inch depth.

Mr. Greenwood said he did not know exactly how those capsules were manufactured, but they were of much softer metal than the base cups, and he thought the brass used for the base cups would be found too hard to be drawn as much as would be necessary for making such capsules out of a single piece of metal without joint.

Mr. H. Chapman believed the manufacture of the capsules involved other points than the softness of the metal used, as he understood similar capsules had been made of steel by the same process.

Mr. Greenwood said he had heard of the steel capsules, and believed they were produced by successive processes of punching, in which case the expense of manufacture would be very great, and the production necessarily slow. In the manufacture of the base cups for the cartridges economy and rapidity of production had been specially kept in view; and they were turned out at the rate of 136,000 per day from a single machine having four punches.

The Chairman enquired whether copper would have been found preferable to brass for forming the base cups, so as to give greater strength to prevent the cartridge case from bursting at the rear in firing.

Mr. Greenwood said many cartridges had been made for the French government with copper base cups; but there was such a want of uniformity in the quality of the copper obtained for the purpose that it was found sometimes too hard and sometimes too soft for satisfactory working. It was therefore now preferred to make the cups of brass of definite composition, whereby a sufficient uniformity of quality was ensured for successfully working the very thin sheets of metal from which the cups were made.

The CHAIRMAN enquired what was the weight of the bullet in the cartridge, and what margin of weight was allowed for variations in the manufacture of the bullets.

Mr. GREENWOOD replied that the weight of lead in the bullet was required to be 530 grains, and the margin allowed for error was only $1\frac{1}{2}$ grains above and below that amount, or 3 grains total variation. That constituted another of the difficulties which had been encountered in the manufacture by machinery, as the exact weight of lead required for the bullet could not be cut off from the original rod of lead within 2 grains at least above and below the required weight; care was therefore taken to cut off enough, and then in the final moulding of the bullet any small surplus was allowed to exude under the pressure through the six small holes made laterally round the outer end of the mould, which acted like safety valves. By this means the bullets were all finished to the required weight within the very small margin of variation allowed. The operation of punching the cylindrical hole in the front end of the bullet, which was itself to be shaped at that part to a parabolic profile, had been attended with much difficulty when it had at first been attempted to be done by a single process, because a cylindrical punch of the form of the finished hole soon became bent; for as the rod-lead had to be of smaller diameter than the die in which the bullet was moulded, in order that it might be fed easily into the cutter-plate and dies, it was not presented quite concentrically to the punch, but lay on the lower side of the die, leaving a space on the upper side until it was forced to fill the die by the pressure applied at the rear. There was thus more lead on the under side of the punch than on the upper side; and consequently when the pressure was applied to form the parabolic curve of the front end of the bullet, the excess of lead on the lower side of the cylindrical punch pushed the punch upwards and bent it. This difficulty had now been got over by the simple expedient of punching a bell-mouthed recess in the front end of the bullet in the first operation, while the profile of the bullet remained entirely cylindrical, the punch used for this purpose being made of a short stiff conical form, instead of the slender parallel form of the

finished hole; and afterwards in the second process the front end of the bullet was closed in upon a cylindrical mandril of the form of the finished hole, so as to make the front hole cylindrical by the same operation which gave the parabolic shape to that end of the bullet, without putting a side strain upon the cylindrical mandril.

Mr. W. Bouch enquired what was the weight of the finished cartridge.

Mr. Greenwood replied that ten cartridges weighed 1 lb., the weight of the powder being 70 grains, the lead 530 grains, and the cartridge case &c. 100 grains.

Mr. W. E. Newton enquired whether the Boxer cartridge was applicable to the "magazine" or repeating rifle; and how many shots that rifle was capable of firing at one loading.

Mr. Greenwood replied that the repeating rifle would fire from seven to fourteen shots at one loading. The Swiss rifle would fire fourteen shots, and had its magazine under the barrel; but this made the gun clumsy to handle, as the weight of the cartridges was added to the weight of the barrel. The American rifle had the magazine in the butt part of the stock, and was consequently more convenient for handling; it contained only seven cartridges, but could be used as a single breech-loader, keeping the magazine full, with as much facility as any single breech-loader yet produced, whilst leaving the reserve in the stock to be fired at the rate of 28 shots per minute. The Boxer cartridge was not applicable to the repeating rifle on account of having a central fire, which rendered the cartridge dangerous in that rifle, because the front end of the bullet would be brought into contact with the percussion cap when the cartridges were placed end to end in the magazine; and a sudden shock, such as might be produced by careless loading or by letting the rifle fall, might explode a percussion cap and fire off the whole magazine. On this account no construction of central-fire cartridge was suitable for the repeating rifle.

Mr. W. E. Newton enquired whether any machinery had been constructed for making blank cartridges for the repeating rifle, to be used for rifle drill.

Mr. Greenwood said he had made machinery for that purpose, by which a number of blank cartridges for drill were manufactured; the bullet was made of pine wood, turned hollow, so that it blew to pieces at three or four yards from the muzzle of the gun, and a person could stand at a distance of five yards from the muzzle without any risk of being injured by the discharge.

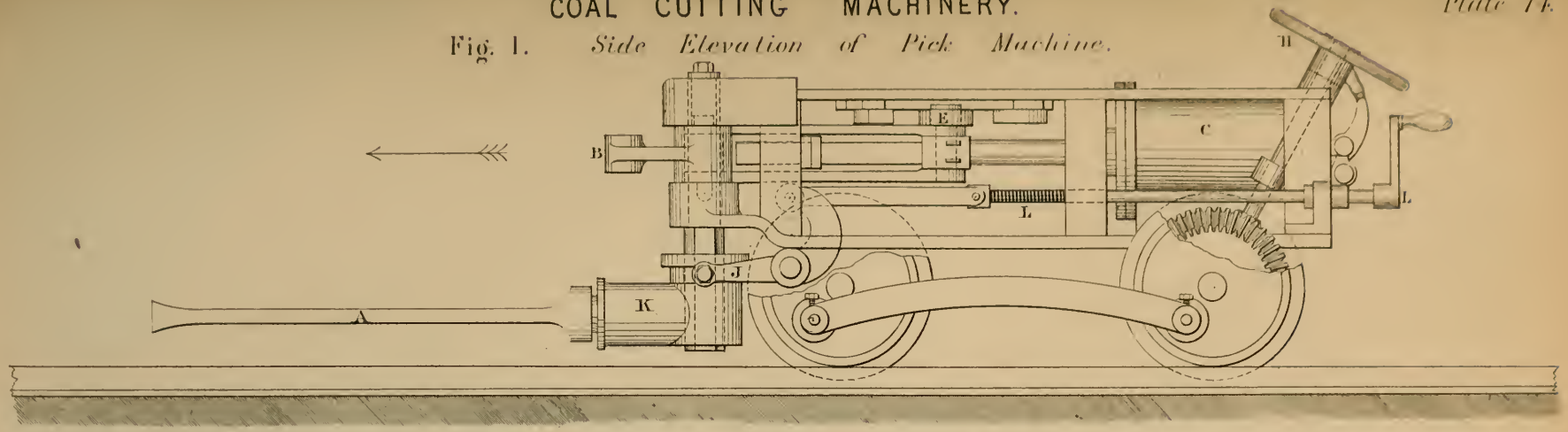
The Chairman said he was sure they all felt greatly indebted to Mr. Greenwood for the amount of trouble he had taken in bringing the subject of the paper before the meeting in so elaborate a manner, and for the very valuable and extensive series of drawings, by which the whole of the machinery employed in the manufacture of the cartridges was so completely illustrated.

He proposed a vote of thanks to Mr. Greenwood for his paper which was passed.

The following paper was then read:—

COAL CUTTING MACHINERY.

Fig. 1. *Side Elevation of Pick Machine.*



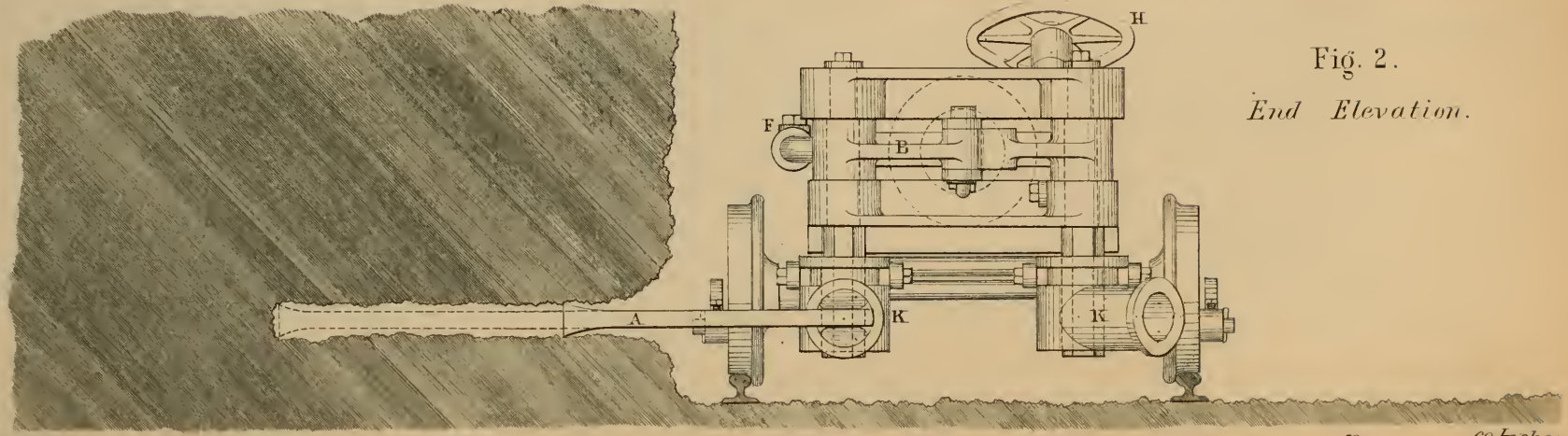


Fig. 2.
End Elevation.

(Proceedings Inst. M. E. 1868.)

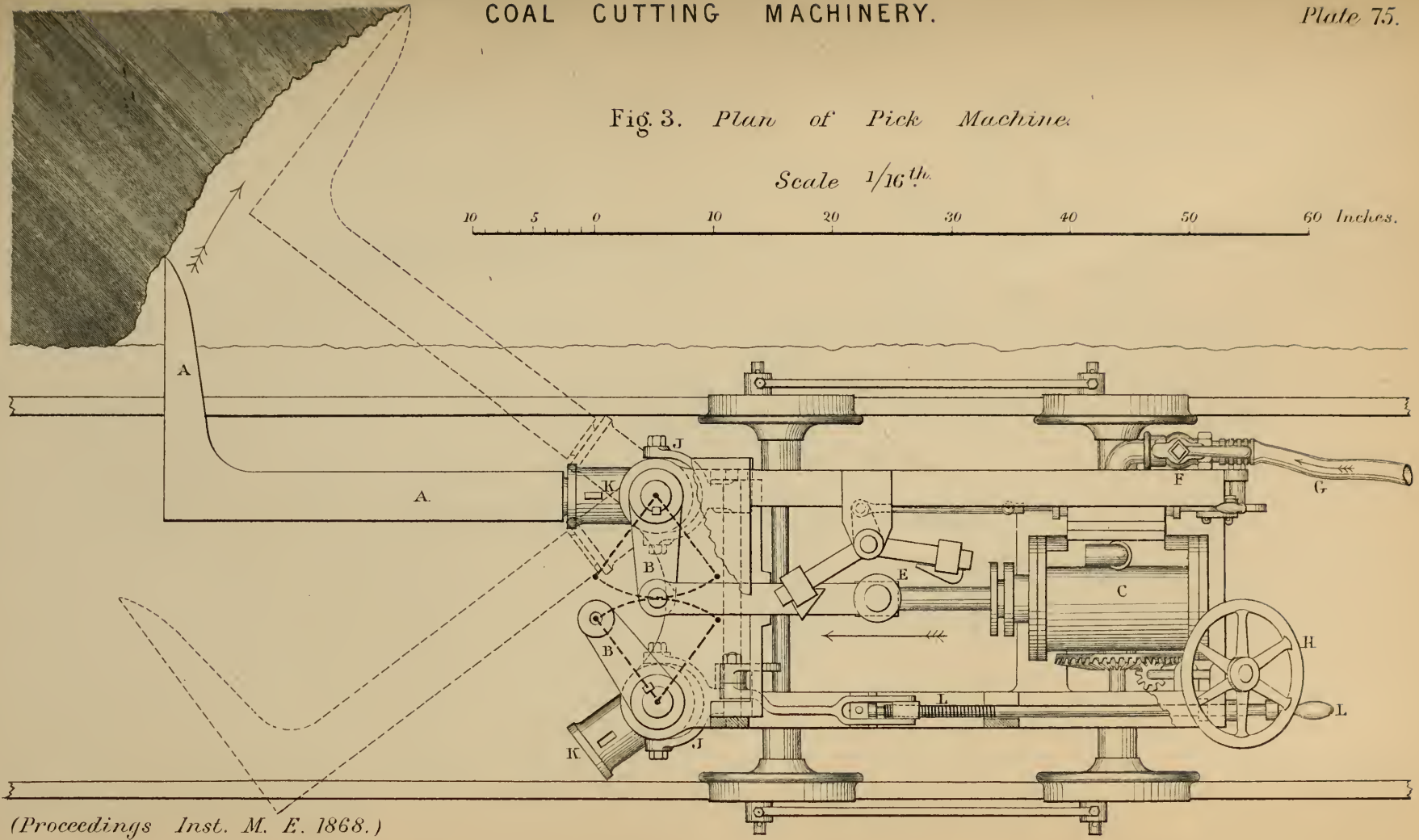
Scale 1/16th.

10 5 0 10 20 30 40 50 60 *Inches.*

Fig. 3. *Plan of Pick Machine.*

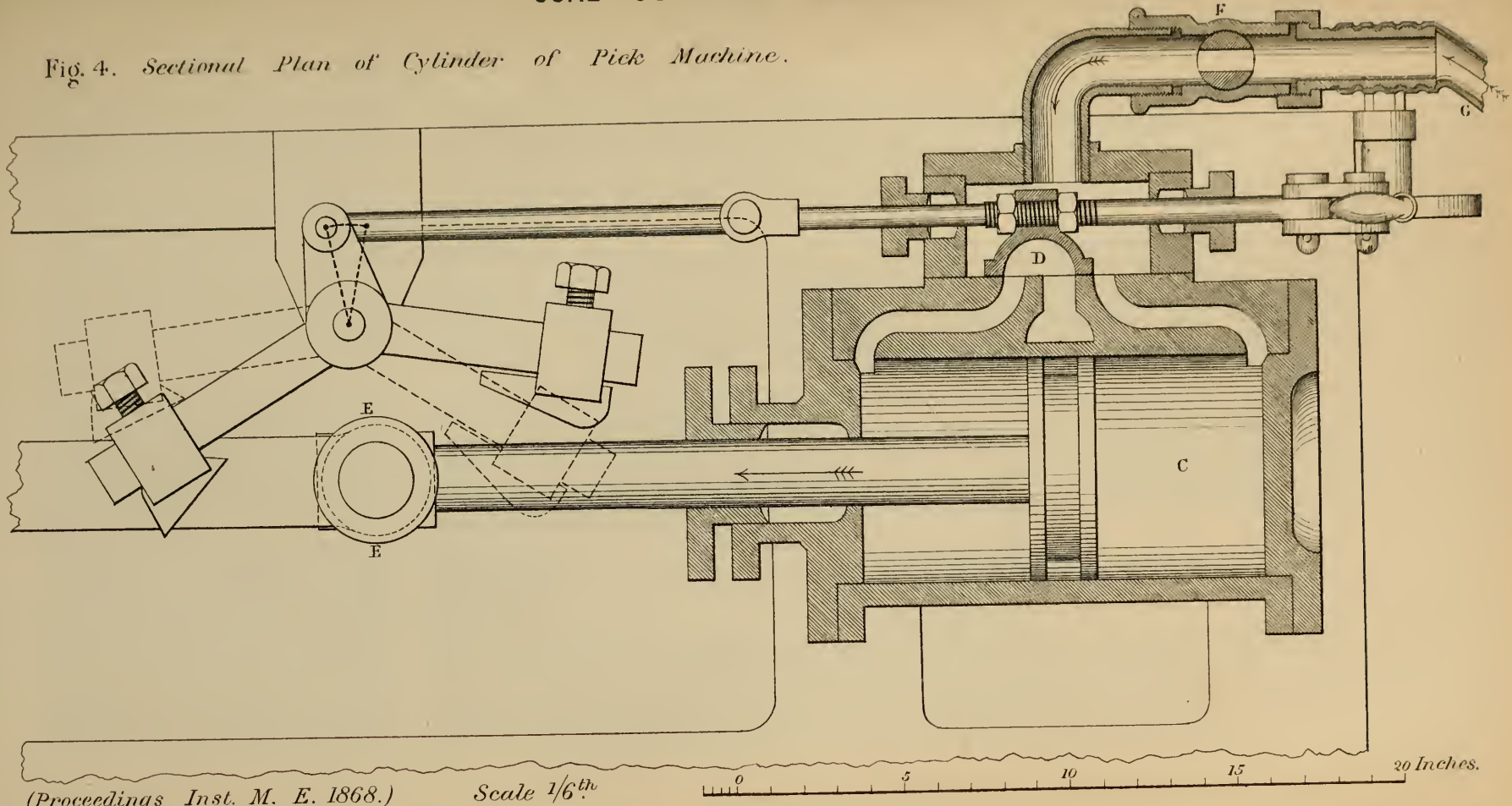
Scale 1/16th.

10 5 0 10 20 30 40 50 60 *Inches.*



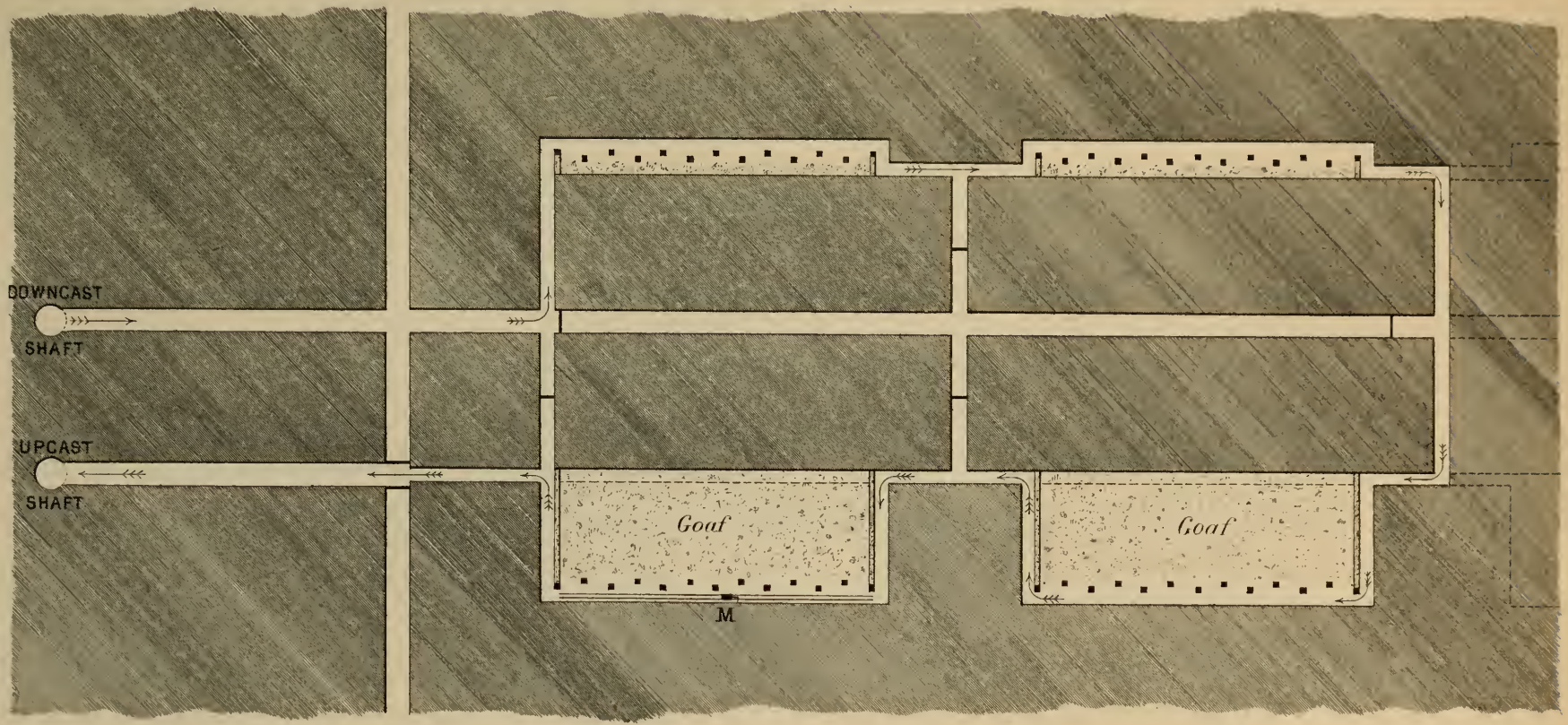
(Proceedings Inst. M. E. 1868.)

Fig. 4. *Sectional Plan of Cylinder of Pick Machine.*



(Proceedings Inst. M. E. 1868.) *Scale 1/6th.*

Fig. 5. *Plan of Working of Colliery by Pick Machine.*



(Proceedings Inst. M. E. 1868.) *Scale 1/1100th.* 10 5 0 10 20 30 40 50 60 70 80 90 100 *Yards.*

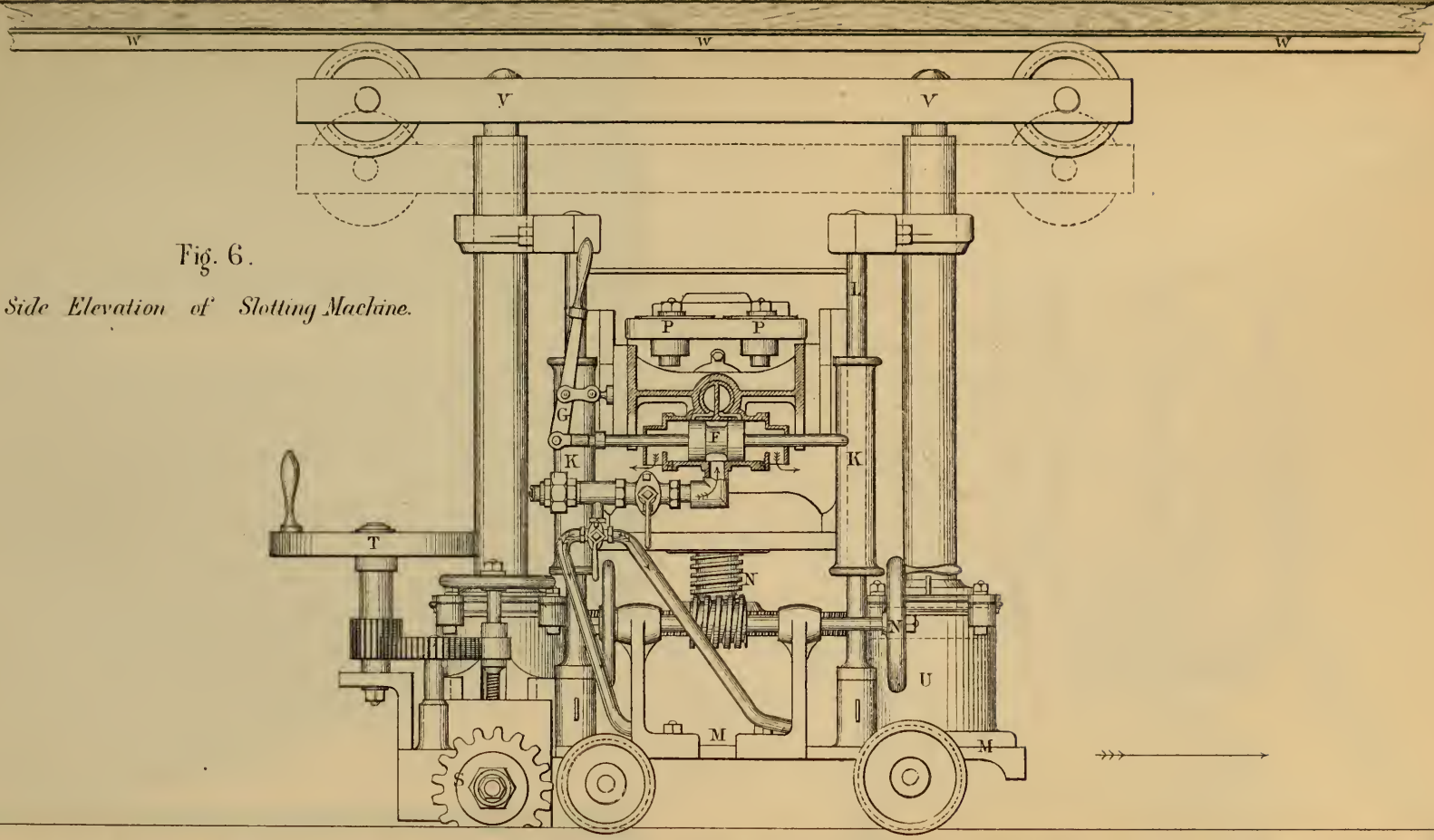


Fig. 6.

Side Elevation of Slotting Machine.

(*Proceedings Inst. M.E. 1868.*)

Scale 1/16th 10 5 0 10 20 30 40 50 60 Inches.

COAL CUTTING MACHINERY.

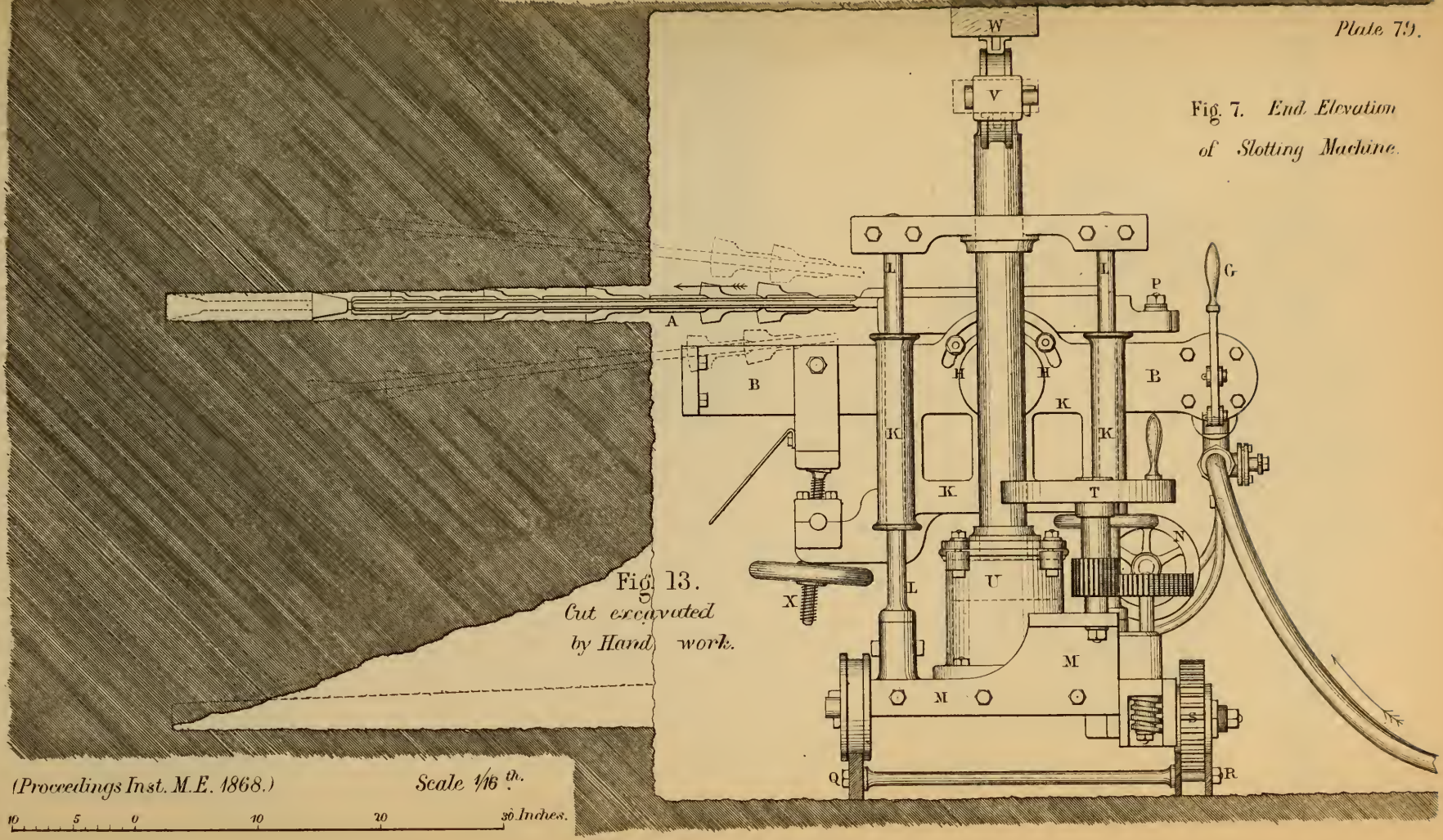


Fig. 7. *End Elevation of Slotting Machine.*

Fig. 13.
Cut excavated by Hand work.

(Proceedings Inst. M.E. 1868.)

Scale 1/16 th.

10 5 0 10 20 30 Inches.

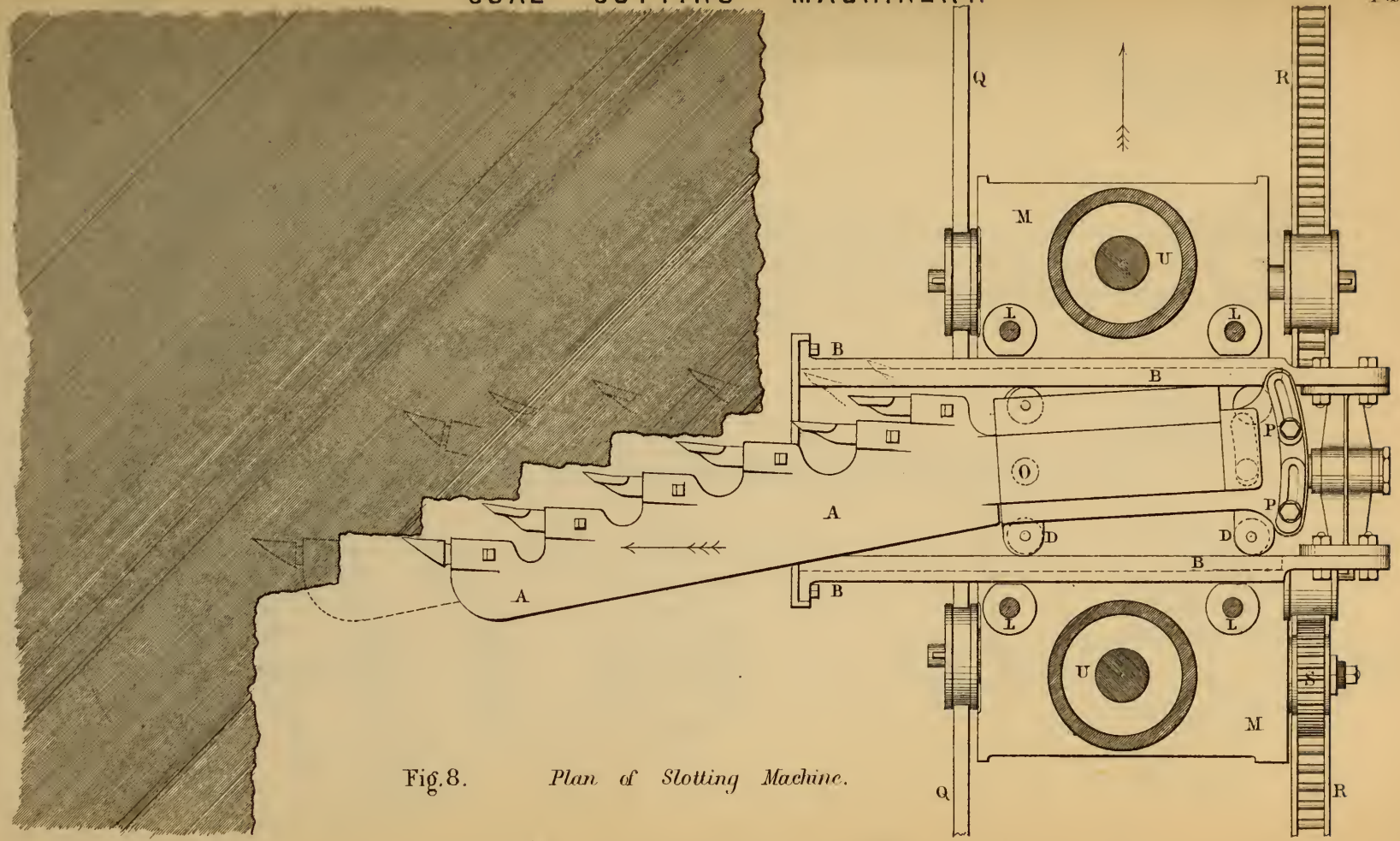


Fig. 8. *Plan of Slotting Machine.*

Scale 1/16 th.

(Proceedings Inst. M. E. 1868.)

COAL CUTTING MACHINERY.

Fig. 9. *Sectional Plan of Cylinder of Slotting Machine.* *Scale 1/8 th.*

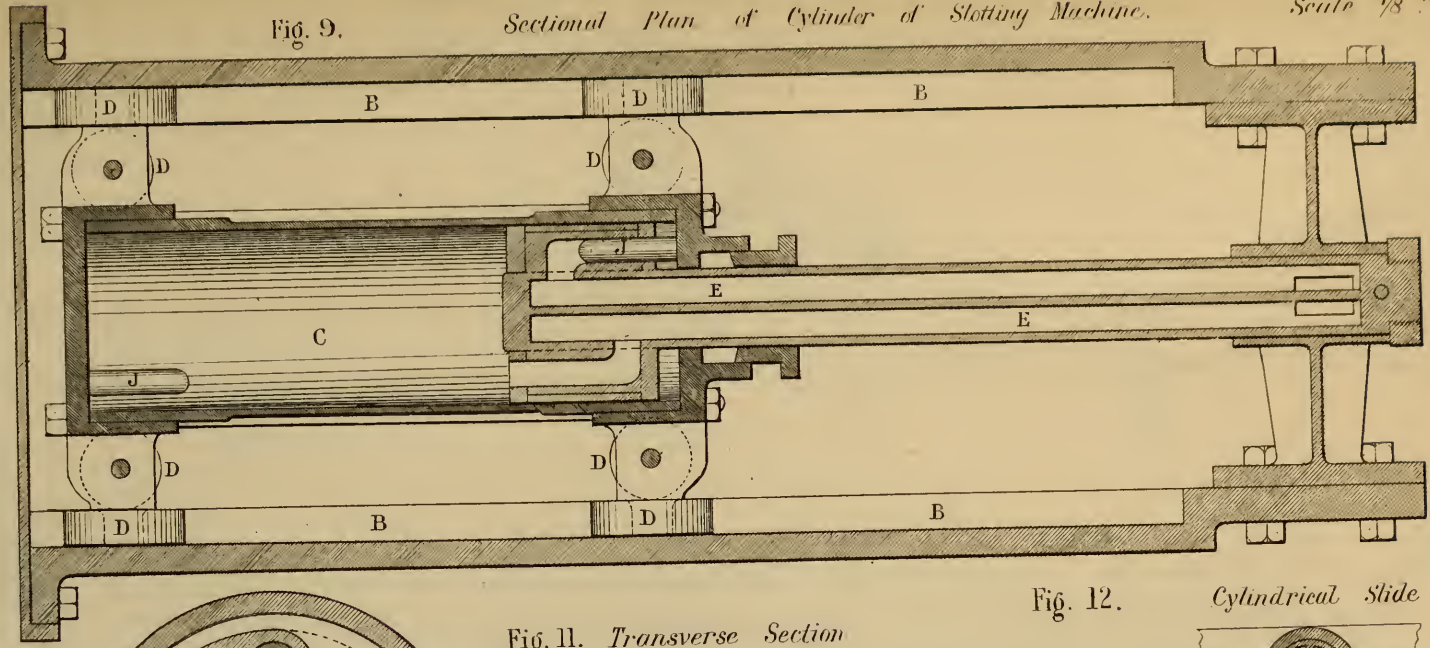


Fig. 10. *Transverse Section of Piston. Scale 1/4 th.*

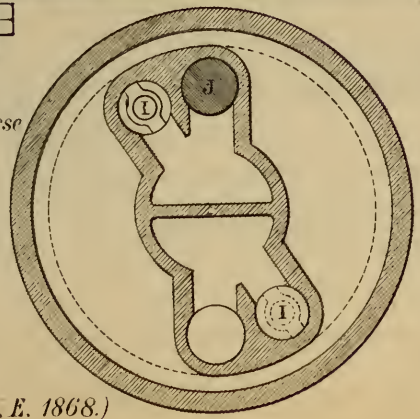
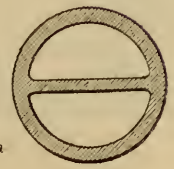
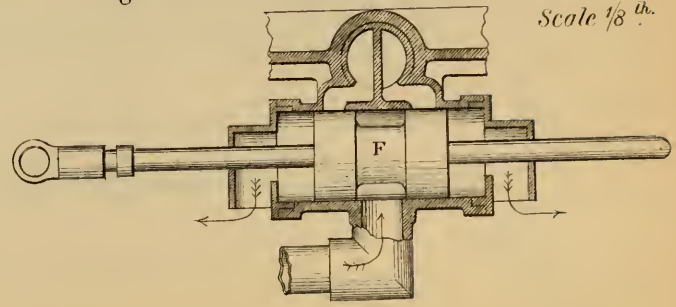


Fig. 11. *Transverse Section of Piston-rod.*

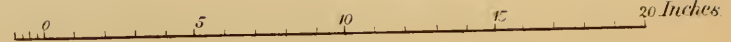


Scale 1/4 th.

Fig. 12. *Cylindrical Slide Valve.* *Scale 1/8 th.*



Scale 1/8 th.



(Proceedings Inst. M. E. 1868.)

WIRE-ROPE TRAVELLING CRANE.

Fig. 1. *Transverse Section of Traveller.*

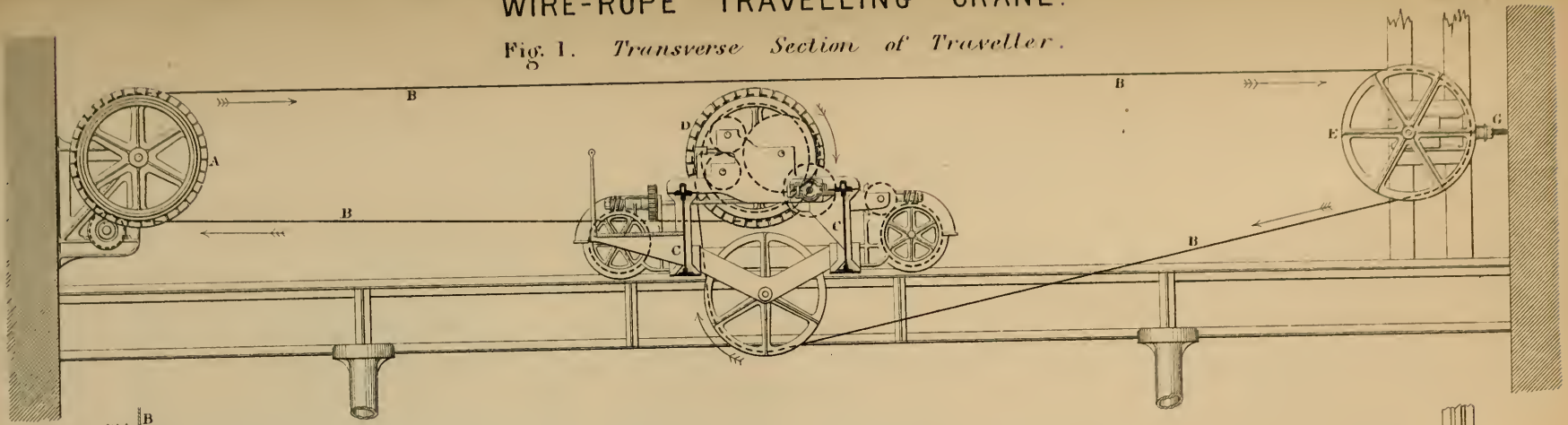
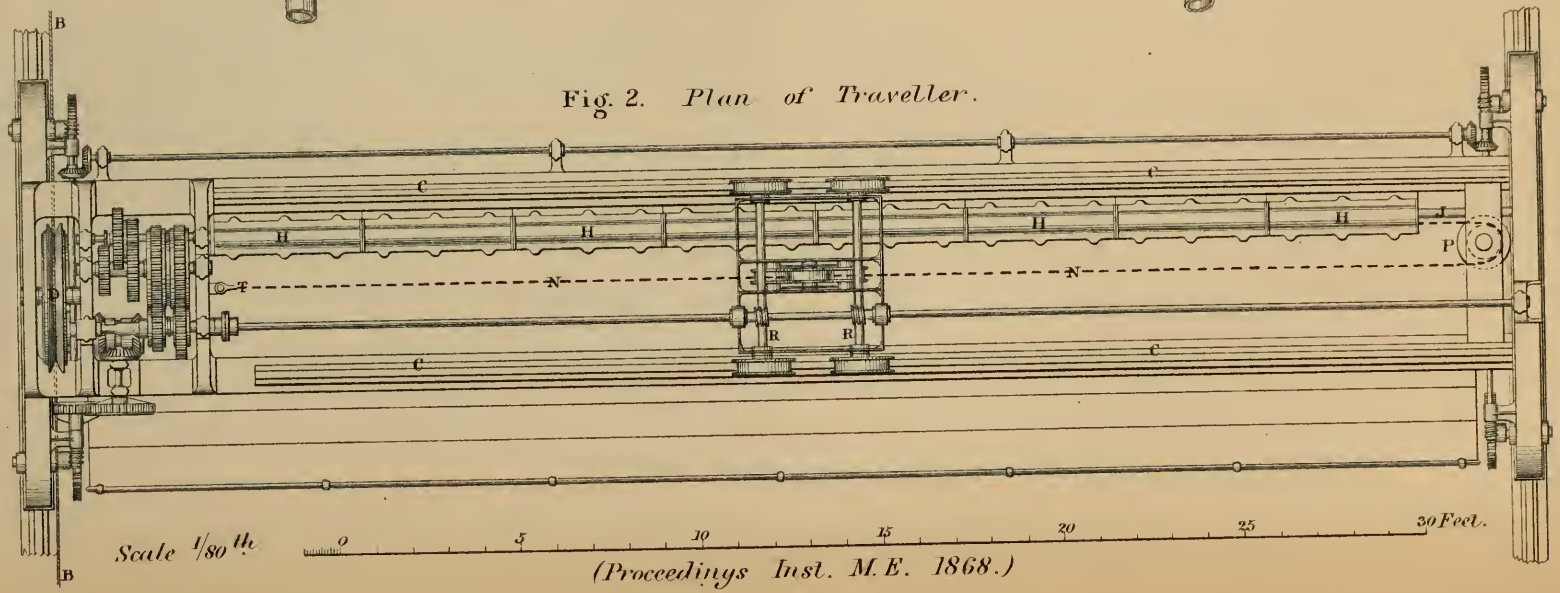


Fig. 2. *Plan of Traveller.*

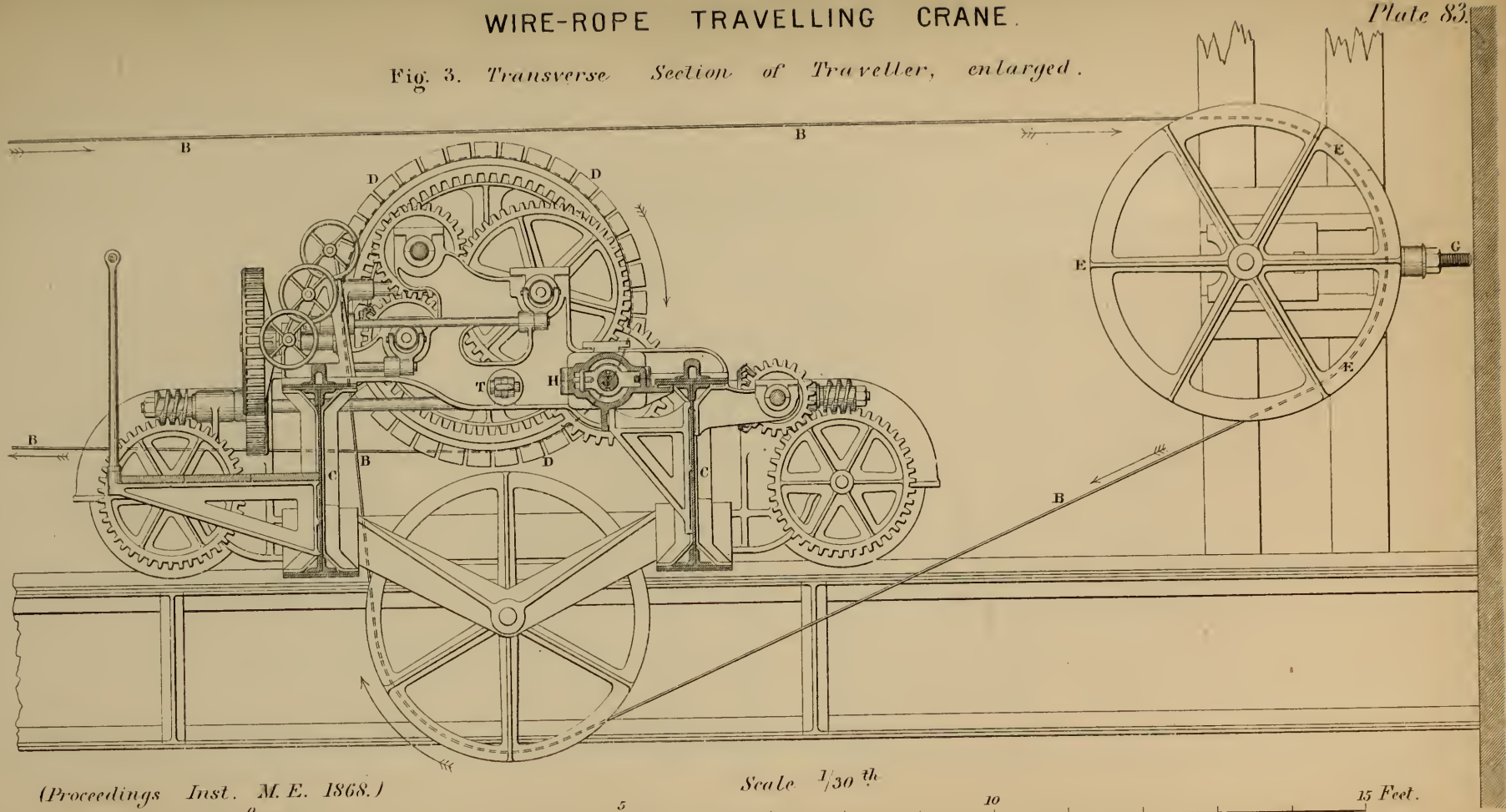


(*Proceedings Inst. M.E. 1868.*)

WIRE-ROPE TRAVELLING CRANE.

Plate 83.

Fig. 3. *Transverse Section of Traveller, enlarged.*



(Proceedings Inst. M. E. 1868.)

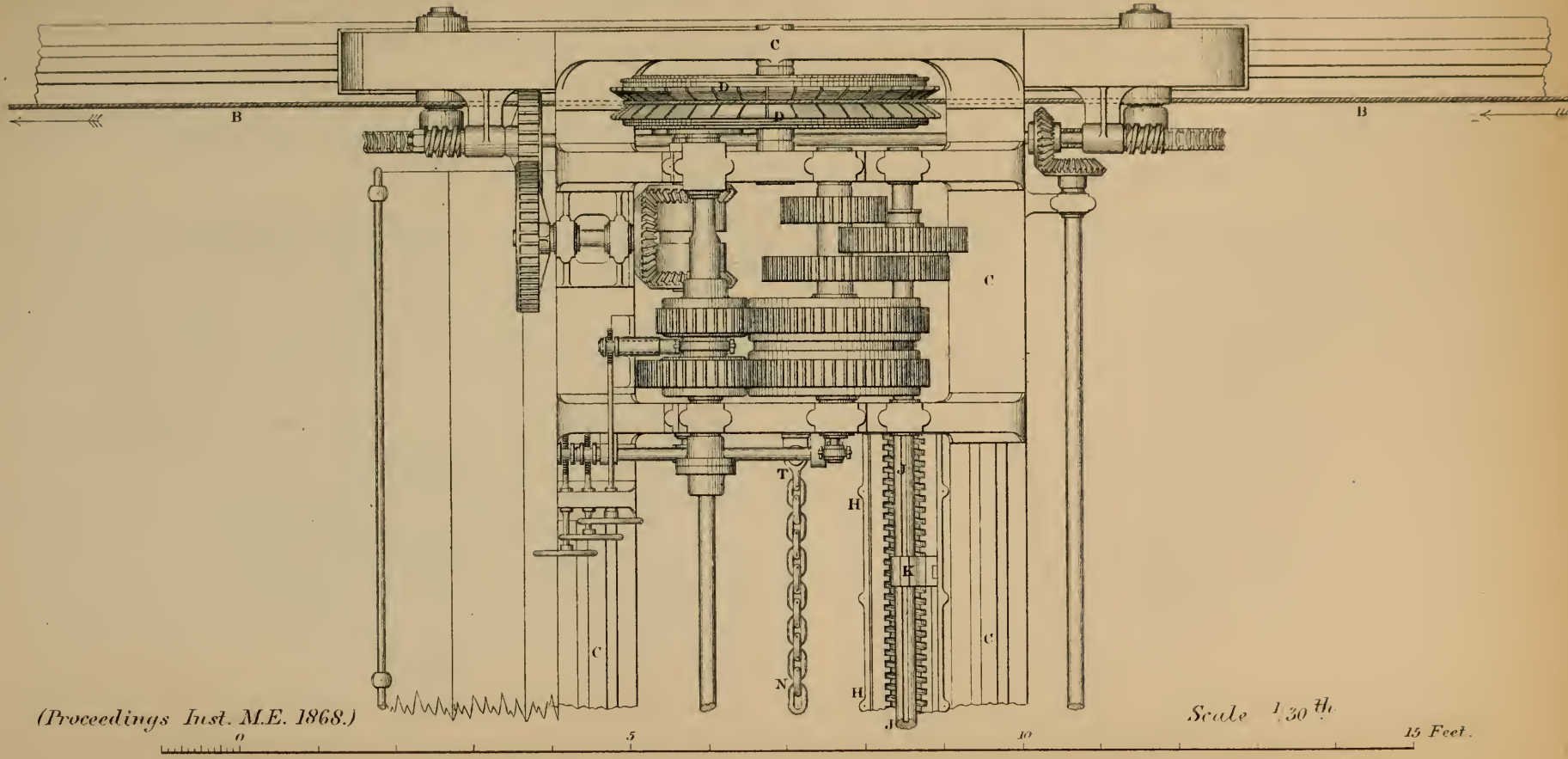
Scale 1/30 th

0 5 10 15 *Feet.*

WIRE-ROPE TRAVELLING CRANE.

Plate 84.

Fig. 4. *Plan of end of Traveller, enlarged.*



(Proceedings Inst. M.E. 1868.)

Scale 1/30 th.

WIRE-ROPE TRAVELLING CRANE.

Fig. 5. *Plan of Hoisting Screw and Screwed Barrel.*

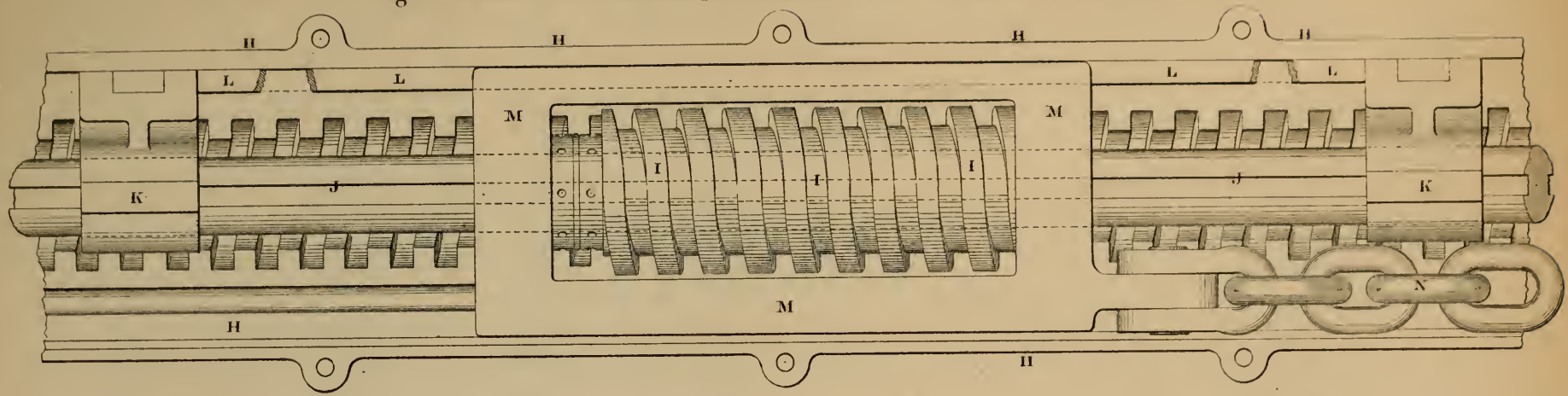


Fig. 6. *Transverse Section of Screwed Barrel.*

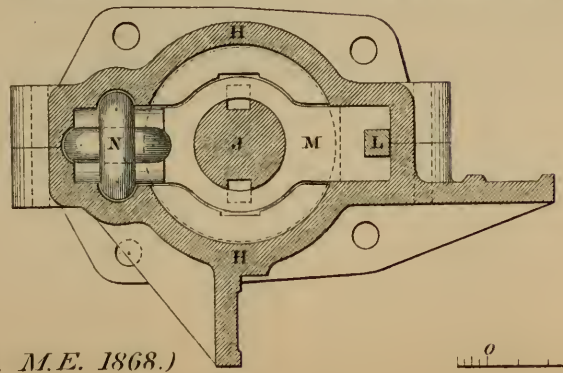
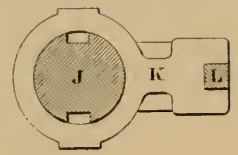
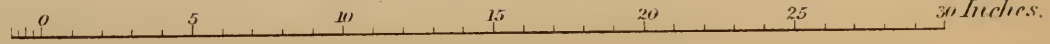


Fig. 7. *Brass Step of Driving Shaft.*



Scale 1/8 th



(Proceedings Inst. M.E. 1868.)

Fig. 8. *Elevation of Cross Traversing Carriage on Traveller.*

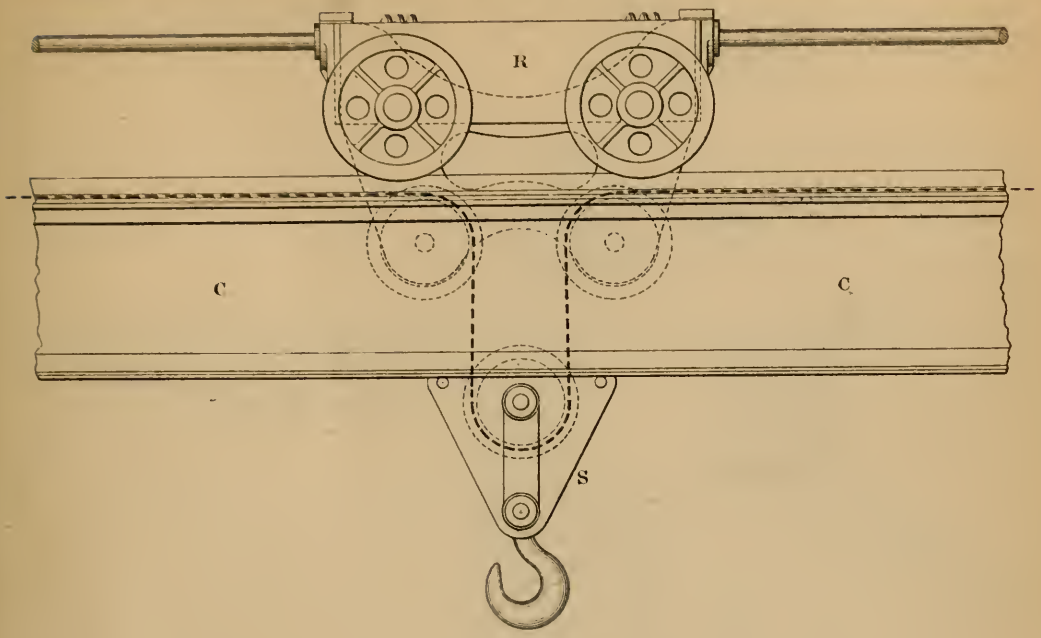
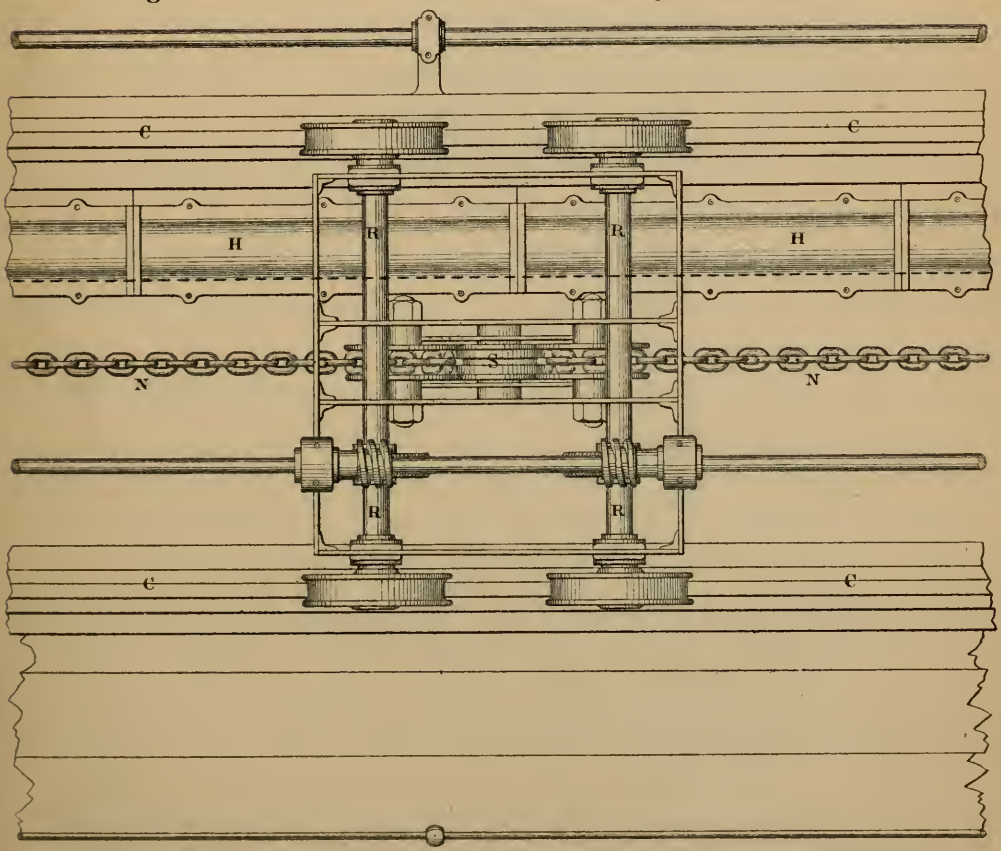


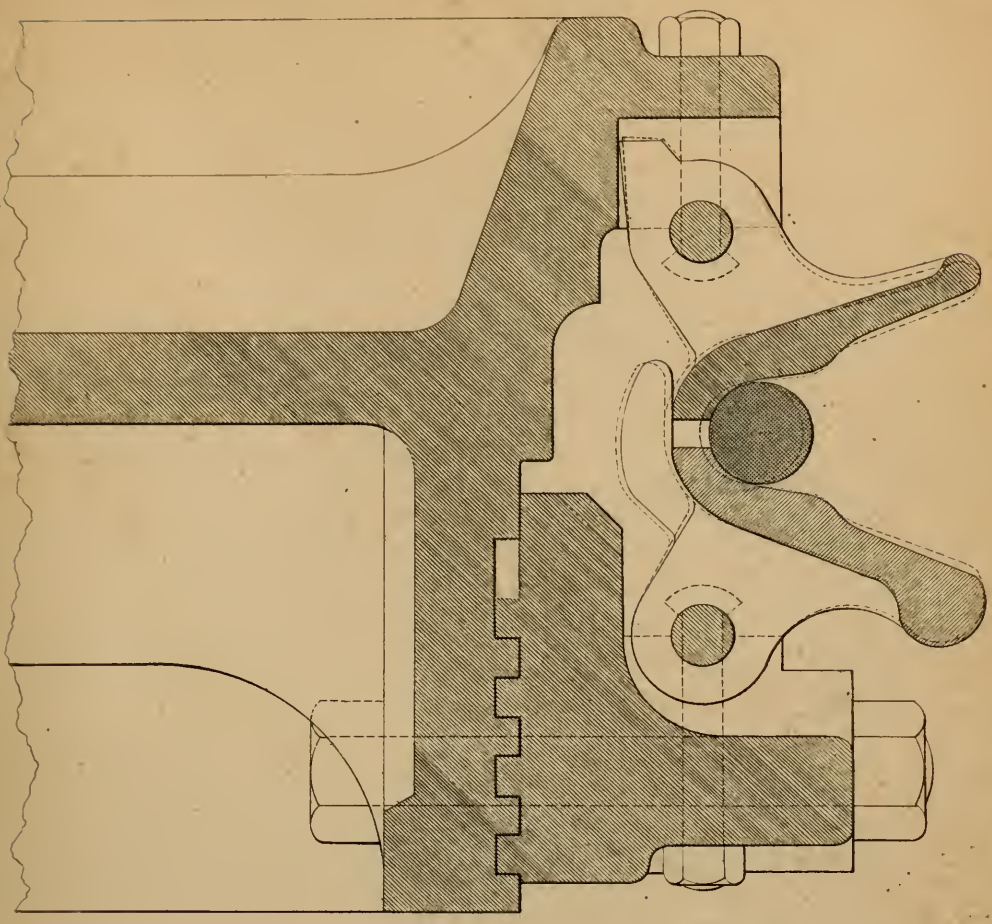
Fig. 9. *Plan of Cross Traversing Carriage.*



(Proceedings Inst. M. E. 1868.) *Scale* 1/30th

0 1 2 3 4 5 6 7 8 Feet.

Fig. 10. *Section of Rim of Clip Pulley.*



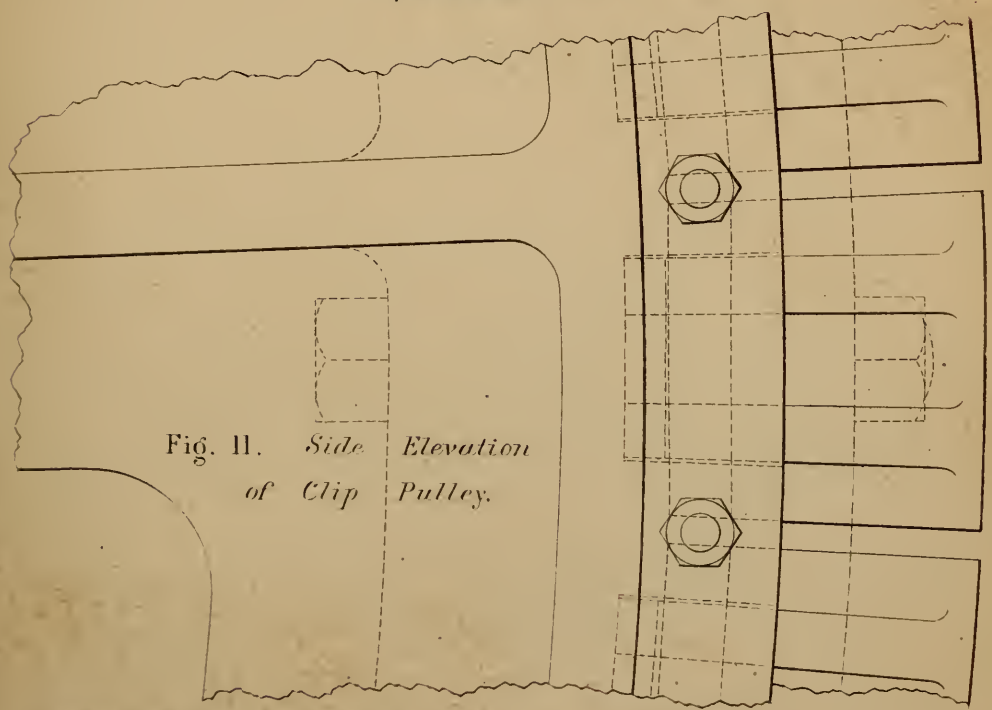


Fig. 11. *Side Elevation of Clip Pulley.*

(Proceedings Inst. M. E. 1868.) *Scale 1/3rd*

0 1 2 3 4 5 6 7 8 9 10 *Inches.*

ON THE APPLICATION OF MACHINERY TO COAL CUTTING.

By Mr. JOHN FERNIE, of Leeds.

The objects to be gained by the application of machinery to Coal Cutting are—firstly, the cheapening of the work; secondly, the saving of a large quantity of coal, which in the ordinary process of holing or undergoing by hand labour with the pick is broken up into slack and dust; thirdly, the removal of the danger attendant upon undergoing by hand labour; fourthly, the getting of a larger quantity of coal out of the pit with the same length of working faces opened; and fifthly, in the case of machines worked by compressed air, the collateral advantage of better ventilation and a cooler atmosphere in the mine, owing to the discharge of the compressed air after each stroke of the tool. The difficulties attending the application of machinery to work previously performed by hand are greatly increased in the case of coal-cutting machines, by their having to work at great depths below ground, and in the very confined passages of a mine.

In the present paper the writer proposes to describe two Coal-Cutting Machines driven by compressed air, one having a pick worked by a bell-crank lever, with an action like that of the ordinary pick used in hand work, and the other working a straight-action tool somewhat in the manner of a horizontal traversing slotting machine. Both these machines have now been successfully employed in regular work for a length of time at collieries in the neighbourhood of Leeds, where they may be seen at work by the Members at the present meeting.

The coal-cutting machine shown in Figs. 1, 2, and 3, Plates 74 and 75, which has been brought to its present state by Messrs. W.

and S. Firth of Leeds, is constructed for working a pick by means of a bell-crank lever, so as to give an action similar to that of the ordinary pick employed in hand work.

The pick A is fixed in a socket in one of the arms of the bell-crank lever B, the other arm of which is worked direct by the piston-rod of the horizontal cylinder C. The slide-valve D, Fig. 4, for the admission and discharge of the compressed air by which the machine is driven, is an ordinary slide, worked by a tappet roller E upon the piston-rod; the machine is thus self-acting as regards the strokes of the pick, which is started to work as soon as the compressed air is turned on by the stop-cock F in the supply pipe G. The machine is mounted upon four wheels running upon the ordinary rails of the colliery, and is advanced the requisite distance between each blow of the pick by a handwheel H connected by gearing with the hind pair of carrying wheels. The two pairs of wheels are coupled together, in order to render the full adhesion available for the forward motion of the machine; and by this means it is found that sufficient adhesion is obtained without the necessity of laying down a special rack-rail for the feed motion.

As the return of the pick after each blow is made by means of the self-acting tappet motion working the slide-valve, it is necessary that the tool should go to the full extent of its stroke at each blow, before it can be withdrawn again. The amount of feed between each blow has therefore to be regulated by the attendant, according to the hardness of the seam of coal in which the machine is cutting, so that the pick shall complete an entire cut at each blow. In the event however of the pick being advanced too far at any blow, so as to put too much work upon it and stop it before the stroke is completed, it is only necessary to draw the machine back again by means of the handwheel H, until the pick is released from the cut; the unfinished stroke is then completed, and the pick goes on working again the same as before the stoppage. In order to allow of altering the height at which the pick performs the holing in the coal, the socket K carrying the pick is made to slide vertically upon the shaft of the bell-crank lever B, the height of the socket being adjusted by the forked arm J controlled by the screwed rod and handle L.

One of these pick machines is now in regular work doing the whole of the undercutting in the West Yorkshire Coal and Iron Co.'s colliery at Tingley near Leeds, holing a seam of coal 3 ft. 8 ins. thick; and the compressed air for driving it is supplied by an air-compressing engine at the surface, with steam cylinder of 20 inches diameter and 3 feet stroke, working an air cylinder of 18 inches diameter and the same stroke, and compressing the air to about 50 lbs. per square inch pressure. The depth of the pit is 170 yards, and the air is conveyed down the shaft and along the mine in $2\frac{1}{2}$ inch cast-iron pipes, with a $1\frac{1}{4}$ inch wrought-iron pipe laid up the bords to the working faces, and then a $1\frac{1}{4}$ inch flexible tube to the coal-cutting machine. Small air vessels are placed at intervals of 500 yards along the air main, for the purpose of maintaining the pressure of the air at the machine, when working at a considerable distance in the mine; the machine is worked at a distance of as much as a mile from the shaft.

In a trial recently made of this machine by the writer, it was found that a pick of 75 lbs. weight, cutting a groove to a depth of 24 inches in from the face, gave about 74 blows per minute. At this colliery the coal is got by the long-wall system of working, as shown in the plan, Fig. 5, Plate 77, in which the machine is indicated at M working along the straight face of 50 yards at one of the banks. The time occupied by the machine in undercutting a length of 56 feet was 25 minutes, including all stoppages for clearing the rubbish out of the hole and for backing the machine when the pick occasionally made an incomplete stroke. The machine was then run back to the starting point, and set to work again with a longer pick of 90 lbs. weight, completing the previous cut to the final depth of 3 ft. 9 ins. in from the face. With this pick the blows were about 60 per minute, and the half length of 28 feet was undercut in 17 minutes, including all stoppages. The time occupied in running the machine back, and changing the pick, was 16 minutes. The machine in this case was working at a distance of about a mile from the bottom of the shaft.

From this trial it appears that in undercutting to the depth of 24 inches in a single course, the work done by the machine was at the

rate of about 30 square yards per hour; and in undercutting in two courses to the total depth of 3 ft. 9 ins., the work was done at the mean rate of about 15 square yards per hour, including the time required for running the machine back and changing the pick.

The width or height of the groove cut out by the pick is 2 inches at the inner extremity, widening out slightly towards the face of the coal. It is necessary to stop the machine at intervals, in order to clear out the rubbish left in the hole; and the rails in front of the machine have also to be cleared of the material thrown out by each return stroke of the pick. Two men are required to attend to the machine, one working the handwheel for the advance of the machine, and the other clearing away the stuff.

A good criterion of the actual rate of working that may be safely reckoned upon with this machine in regular practice is afforded by its performance upon an occasion when it was kept continuously at work for 24 hours consecutively, on 21st and 22nd of May last. During this time the machine was employed upon five different banks of coal successively, requiring accordingly to be shifted four times for the purpose. The average depth of holing was 3 ft. 6 ins., and the total length of work completed to that depth during the 24 hours amounted to 257 yards. This gives the practical rate of holing by the machine at rather more than 12 square yards per hour, including all stoppages for clearing the pick in working and for shifting the machine on the completion of each separate length of bank.

The other coal-cutting machine to be described, which is shown in Figs. 6, 7, and 8, Plates 78 to 80, is the invention of Mr. G. E. Donisthorpe of Leeds, and may be described as a horizontal traversing slotting machine, the work remaining stationary, while the machine traverses along the working face of the coal and cuts out a horizontal slot or groove along the bottom of the seam of coal or along a parting in the thickness of the seam itself.

The cutter bar A carrying the cutting tools is fixed upon the upper side of the working cylinder C, which moves horizontally forwards and backwards at each stroke, the piston and piston-rod remaining stationary. This arrangement has the advantage of

economising space, and giving greater stiffness and a better attachment of the cutter bar; and the whole is guided steadily between the guides B B, by means of four sets of steel rollers D D attached to the cylinder and steadying it both vertically and laterally, as shown in the sectional plan of the cylinder, Fig. 9, Plate 81. The piston-rod E is made hollow, as shown in Figs. 9 and 11, having two passages communicating with the opposite sides of the piston; and the alternate admission and exhaustion of the compressed air is regulated by a cylindrical slide-valve F, Figs. 6 and 12, worked by the hand lever G. The ports in the piston are circular, and at each end of the cylinder a projecting plug J is fixed on the inside of the cover, opposite to the port, as shown in Figs. 9 and 10; this plug entering the port at the end of the stroke prevents the complete escape of the whole of the air in exhausting; and the air thus retained in the cylinder forms an air cushion at the end of the stroke, whereby the piston is prevented from striking the cylinder cover at either end. A subsidiary port I, Fig. 10, alongside the main port, and provided with a valve opening outwards, affords a passage for the admission of the compressed air at the commencement of the next stroke, until the main port is unstopped by the withdrawal of the plug J.

The working cylinder C is 6 inches diameter with 12 inches stroke; and the frame B in which it is carried is itself slung upon horizontal trunnions H, Fig. 7, in another frame K sliding vertically upon the pillars L L, which are fixed on the base-plate M of the machine; and by means of a screw N and worm-wheel, Fig. 6, the working cylinder can thus be raised or lowered bodily to any height at which the cutter is required to work. The trunnions and the curved slot H, Fig. 7, also allow of the cutter being adjusted by means of the handwheel and screw X to work at an inclination to the horizontal, between the limits shown by the two dotted positions in Fig. 7.

The cutter bar A, Figs. 7 and 8, is of cast steel, having six sockets for carrying the cutting tools. The tools are made of flat bar steel, with one-quarter twist in the shank, by which means the cuttings are thrown away from the face of the cut at each stroke of

the bar A. The cutters are placed about 7 inches apart longitudinally along the length of the bar A, the average depth of the cut being about 3 ft. 4 ins. in from the face of the coal; and the length of stroke being 12 inches, the tool does no work during the first 5 inches of the stroke, but acquires a rapid motion whereby it strikes upon the coal with the percussive action of a blow, instead of cutting by a uniform steady pressure like an ordinary slotting tool. Previous to the adoption of this principle of working, the present pressure of air of 60 to 70 lbs. per square inch was found insufficient to work the machine; but with the percussive action now obtained this pressure is found completely effective, and the diameter of the working cylinder being 6 inches, the blow is given with a total force of 1700 lbs. or $\frac{3}{4}$ ton upon the tool. The cutters are stepped $2\frac{1}{2}$ inches successively in advance of one another, as shown in the plan, Fig. 8, Plate 80; and the bar is fixed upon the working cylinder by a centre pin O and set screws P P, allowing it to be set obliquely in plan at an inclination to the line of the stroke, as shown by the dotted lines in Fig. 8. By this arrangement the inclination of the cutters to the work can be slightly increased or diminished, according as may be required by the quality of the coal, so as to obtain under all circumstances the most effective action of the cutters. The width of their cutting edges ranges from $1\frac{3}{4}$ inches in the cutter at the outer extremity of the bar to 3 inches in the cutter nearest the working cylinder; and the slot cut out by the machine is therefore of the slightly tapered form shown in Fig. 7, Plate 79.

The machine is mounted on four double-flanged wheels, Fig. 8, Plate 80, running on rails laid for the purpose. The rail on one side is a plain wrought-iron bar Q placed on edge; and the other rail R is made of two bars placed 2 inches apart, with a series of cross pins at $1\frac{1}{2}$ inch pitch, forming an open rack-rail, into which gears a pinion S worked by a handwheel T, whereby the machine is advanced for each cut, the ordinary amount of feed being $1\frac{1}{4}$ inch per cut. As the advance is given by hand by the man working the machine, any number of strokes can be given by the tool before the machine is moved forwards, in case the coal is too hard for the cutters to accomplish the full depth of cut at a

single blow. The traversing pinion S gearing into the rack rail is mounted in a slide on the base-plate M of the machine, whereby it can be raised out of gear with the rack when the machine has to be drawn away from one part of the mine to another.

The pressure of the air working the machine is also employed for steadying it against the blows of the tool, so as to ensure the full effect of the blow being expended upon the coal at each stroke; otherwise the tool would be liable to be bent or broken, and the work would be irregular. This is accomplished by means of two vertical cylinders U U, each $8\frac{1}{2}$ inches diameter, the piston-rods of which stand up towards the roof of the mine, and are connected together at the top by a horizontal frame V carrying a grooved wheel at each end. A loose iron rail on a wood batten W is placed above the grooved wheels; and the compressed air being admitted on the underside of the pistons in the cylinders U, the rail is pressed up against the roof of the mine, as shown in Figs. 6 and 7. The total pressure exerted by the pair of cylinders U U amounts to 6800 lbs. or upwards of 3 tons, which is found amply sufficient to resist the blow of the tool. When the machine in its forward traverse has arrived at the end of the roof rail W, the pressure is shut off from the cylinders U, and the air is let out from them through cocks opened by hand, thus lowering the frame V as shown by the dotted lines in Fig. 6; the roof rail is then shifted forwards to the extent of its length, and the pressure being readmitted to the cylinders U, the machine is again ready for continuing its forward traverse as before. The pressure exerted against the roof being elastic allows the top rail to accommodate itself to any irregularities in the level of the roof.

The working of this coal-cutting machine having been witnessed recently by the writer at the West Riding Colliery of Messrs. Pope and Pearson, at Normanton near Leeds, it was observed that the number of strokes made by the tool was from 75 to 80 per minute, the pressure of air at the machine being from 65 to 70 lbs. per square inch at the time. The average depth of the cut during the time of observation was about 2 ft. 9 ins., as there was a clearance space of more than 1 foot left between the side of the

machine and the face of the coal, the rails not having been laid close enough to the face of the coal. The width of the cut is about 2 inches at the inner end, widening to about 3 inches at the face of the coal; and as the cut was in this case being made in a parting of dirt of about the same thickness, no waste of coal was produced by cutting the groove. One man is required to work the machine, working the air valve F by the hand lever G, Fig. 6, and also giving the feed of the tool by the handwheel T advancing the machine; and from 3 to 5 strokes were given by the tool between each advance of the machine, for completing the cut to the full depth of the groove; about three turns were then given to the traversing handwheel, advancing the machine about $1\frac{1}{4}$ inch, after which the same number of strokes were again given with the tool. The cuttings are cleared out of the groove by a man following the machine with a narrow curved rake; and the height of the cutting tool in the machine is regulated occasionally, according to the slight variations in the level of the parting in which the groove is made, so as to keep the tool always working in the parting.

The width of the groove cut by this machine is shown in Fig. 7, the width at the face of the coal being not more than about $3\frac{1}{4}$ inches in holing to the full depth to which the machine can work. In undergoing by hand to the same depth, the size of the cut is as shown in Fig. 13, Plate 79, having a width of at least 13 inches at the face of the coal, making the whole size of the cut about three times that of the narrow groove excavated by the machine, which is shown by the dotted line in Fig. 13. Supposing the machine to be holing in the solid coal, the waste produced by the undergoing in a seam of 5 feet thickness, such as is being worked at the West Riding Colliery, would amount to only about 4 per cent., as compared with about 12 per cent. waste with hand work. An estimate of the absolute quantity of waste made by hand work in good seams of coal amounts to as much as 12 per cent., the whole of which is rendered nearly worthless; and taking the whole quantity of coal raised per annum in this country at 100 million tons, the waste produced in undergoing by hand labour amounts consequently to as much as 14 million tons per annum.

The compressed air for working the machine is supplied by an air-compressing pump of 18 inches diameter and 2 ft. 10 ins. stroke, worked by an engine that is employed for winding coals up an incline at the bottom of the pit. The compressed air is delivered by the pump into a large air-vessel, 3 feet diameter and 30 feet long, from which it is conveyed along the mine by a wrought-iron pipe $2\frac{1}{2}$ inches diameter and $\frac{1}{4}$ inch thick, put together with ordinary screwed sockets, and terminating in a portion of $1\frac{1}{4}$ inch pipe and a long length of flexible tubing of the same size, which is coiled on the floor and drawn out by the machine as it advances along the face of the coal. Great difficulty was originally experienced in maintaining the pressure of the air at the machine when working at considerable distances from the compressing pump; but this has been completely obviated by the introduction of a second smaller air-vessel at the working face where the machine is in operation. This smaller air-vessel is 2 feet diameter and 6 feet long, and is mounted on wheels for the convenience of being quickly removed to any part of the mine. The air-compressing pump is capable of supplying air enough for working three of the coal-cutting machines, but at present there is only one machine working in the pit. There is not therefore the means of ascertaining the actual cost of the steam power required to work the machine; but there is no doubt a great saving over hand labour by the use of the machine.

By the adoption of compressed air as the medium for transmitting the power to work these coal-cutting machines, the important collateral advantage is obtained of improved ventilation at the working faces. The discharge of the exhaust air from the machines delivers a supply of fresh air, free from noxious gas, during the whole time that the machine is working; and the coldness of the discharged air, consequent upon its expansion at the moment of liberation, has a highly beneficial effect in reducing the temperature at the working faces. During the trial made by the writer at the Tingley Colliery, a shot was fired at a short distance from the machine, for breaking down a mass of coal; and although the smoke at first completely obscured the working face and the machine, the whole of it was

cleared away in so short a time as two minutes, having been carried off by the current of exhaust air discharged from the machine. In the case of any danger arising from accumulation of gas in the goaf or elsewhere, the means of safety is at hand, as it is only necessary to detach the india-rubber supply pipe from the machine, and discharge a continuous jet of fresh air in the required direction, whereby the gas is speedily dispersed, and the dangerous place rendered safe. Also as the undercutting of the coal is done so much quicker by the machines than by hand labour, the employment of the machines requires a smaller extent of working faces to be kept open for getting the same quantity of coal in the same time; the air has therefore a shorter distance to travel and becomes less loaded with gas, and is consequently safer and more wholesome for the colliers.

In reference to the greater quantity of coal that is got by the use of the machine from a given length of working face in a given time, the quantity got by one man in a day, including undercutting, breaking down, and filling the coal, is 3 tons when undercutting by hand labour, assuming a yield of one ton of coal per cubic yard; and taking a working face of 48 yards length, the four men working on that length of face would therefore get 96 tons in 8 days. The machine however will undercut 96 yards in one day, and this quantity would then be broken down and filled in by four men in two days, making only 3 days for getting the 96 tons with the machine, in comparison with the 8 days required for hand labour. Hence with the machine as much coal can be got from 18 yards length of face as from 48 yards by hand in the same time.

In regard to the danger to which the collier is exposed in holing by hand labour, from the risk of the coal falling down and crushing him while lying with his body inserted partly within the groove which he is excavating, it is evident that this danger is entirely removed by the employment of a machine for performing the holing, as the men are altogether clear of the working face, and the tool alone enters the groove in process of excavation.

Mr. FERNIE observed that, as some of the earliest attempts at coal-cutting by machinery had been made in the neighbourhood of Leeds, he thought a paper on the subject would be appropriate for the present meeting, especially as the opportunity would be afforded to the members of seeing at work in the same colliery the two different machines described and exhibited to the meeting. Both machines he believed were now proved by the results of actual working to be completely practicable; and he had been much gratified at finding that coal-cutting by machinery was no longer merely an experiment, but that at the Tingley Colliery the whole of the undercutting of the coal, excepting only in driving headings, was at the present time being done by the pick machine, as described in the paper. The removal and relaying of the rails at the working face, as the getting of the coal advanced, was managed in a very simple way at that colliery, by merely turning up sideways against the face of the coal the pair of rails with their sleepers, so as to allow of fixing the new row of props close to the face of the work immediately after the machine had passed along and finished the cut; and the rails were then ready for turning down again into the further position required for the next cut, as fast as the coal already cut was got out and loaded into the corves; by this plan the rails were relaid with the least possible trouble, ready for the next traverse of the machine along the new face of the work.

Mr. W. FAIRBAIRN observed that the groove cut by the machines shown in the drawings was represented at a considerable height above the floor of the mine, and he enquired whether it was necessary for the holing to be done so high up in the seam.

Mr. FERNIE replied that in the position shown in the drawings the machines were holing in a parting of dirt situated at that height above the floor, so that the holing was not done in the coal itself but in the parting; but both machines were arranged for holing also at a lower level, according to the height at which the cut had to be made. In the slotting machine the cylinder carrying the cutter was made to slide vertically on four guide bars; and in the pick machine the height of cut was adjusted by simply sliding the pick itself upon the vertical shaft on which it was keyed, and by this means it

could be set to hole in the very bottom of the seam, at the level of the rails.

Mr. W. Naylor observed that as the machine was holing in a parting of dirt it had the advantage in that case of undercutting the coal without waste of the coal itself; but in holing half way up the height of the seam, as was there the case, only the upper half of the coal above the cut would be brought down by the creep of the roof, while all below the cut would have to be got out by wedging. He enquired therefore whether it would not be better to hole at the bottom of the seam so as to bring the entire thickness of the coal down at once, instead of in two stages; as he thought such a mode of working would be particularly desirable where the seams of coal were not very thick, like those mentioned in the paper of only 5 feet and $3\frac{1}{2}$ feet thickness. In the slotting coal-cutting machine described in the paper the use of compressed air for working the machine gave a percussive action to the stroke of the tool; but in another machine upon the slotting principle that had been used for coal cutting, the power employed was water pressure, so that the tool was worked with a more gradual and steady movement, like a planing or slotting machine for iron; and he thought it would be of much interest if some information could be given as to the relative value of the two machines worked in these different ways. Any machine which was successful in accomplishing the work of undercutting the coal ought he considered to receive the greatest encouragement from all connected with collieries, as he believed there would be far less liability of strikes among the men where the holing was done by a machine; for although no doubt colliers were difficult to deal with, this was probably due in a great measure to the severe nature of the bodily labour involved in holing, which inclined the men to abandon their work upon the most trivial pretexts; whereas if a machine were employed for the holing, they were spared the heaviest part of the work, and had nothing to do beyond getting out the coal undercut for them by the machine. Moreover to the colliery owners themselves a holing machine would be invaluable in the event of a strike, by enabling them in the emergency to continue the working of the colliery without being dependent upon the regular colliers.

Mr. FERNIE said that at the colliery referred to in the paper advantage had been taken of the dirt parting in the middle of the seam to do the holing at that height so as to avoid wasting the coal; the top portion was then got out first, being brought down by the creep of the roof, aided by a few shots where necessary; and the bottom part was afterwards broken away by wedging, which was easily accomplished when the top coal had been previously removed. In ordinary cases, where there was no special object in holing above the level of the bottom of the coal, the undercutting would of course be done by the machines at the bottom, according to the usual practice in undercutting. One great inducement to the adoption of a machine for holing had been the difficulty frequently experienced in getting men to do the holing at the bottom of a seam, on account of the great danger they were then exposed to from the creep of the roof bringing the large mass of coal down upon them unawares.

Mr. W. FIRTH explained that another important reason for holing in the parting at the Tingley Colliery, instead of at the bottom of the seam of coal, was that the parting in the seam was a line of division between two different qualities of coal, as was generally found to be the case, the coal above the parting being in this instance of a better quality than that below. If the holing were done at the bottom, so as to bring down the entire thickness of the seam at once, the good quality of coal would get mixed with the bad; and it was therefore better to keep the two sorts separate, by cutting the groove in the parting between them, and breaking down the upper and better portion before getting the bottom coal.

Mr. W. FAIRBAIRN observed that not only would the use of a machine for holing prove a great boon to the working collier, by sparing him a great deal of painful toil in undercutting the coal, but it appeared that it was also of great commercial importance to the owners of collieries, by enabling them to get a larger quantity of coal out of the mine in the same time, and with less waste of the coal in holing. In working the machines by compressed air there was the further advantage that the ventilation was improved at the working face by the discharge of the cylinder full of fresh air at each stroke of the machine. Another consideration

which struck him as important was that he had observed in the north of England pits that it was sometimes necessary, after undercutting the coal at the bottom by hand, to cut also some vertical slits, in order to bring the coal down in mass; but the facility afforded by the machine for holing in a higher part of the seam, leaving a smaller thickness of coal above the cut, would enable the upper coal to be brought down in mass without more trouble than applying a shot at the top. There would be no difficulty afterwards in getting out the bottom coal below the groove. The adoption of coal-cutting machines was therefore well worthy of consideration, and he hoped before long to see them extensively substituted for hand labour, more particularly as he understood machines were gradually being introduced at several collieries in different parts of the country.

Mr. W. Menelaus said he had long been looking for a good practical coal-cutting machine, but the subject was surrounded with many difficulties, on which he thought hardly sufficient consideration had been bestowed. In the first place, if the machine were to do a large proportion of the whole work of the colliery, its introduction would be a comparatively simple matter, because it would unquestionably be of great and immediate commercial advantage. But so far was the holing of the coal, which was the only operation performed by the machine, from forming a large proportion of the entire work of a mine in South Wales, that he considered the holing did not amount there to more than one tenth of the entire work. Although therefore the undercutting was no doubt the hardest and most disagreeable labour in a colliery, it would evidently be difficult to introduce with economy a machine which would only deal with so small a proportion of the work; and he thought this would prove the chief practical difficulty in the way of introducing coal-cutting machines.

With regard to the effect produced upon the ventilation by the air discharged from the machine, he thought the quantity so discharged must be very small compared with the total quantity required for the ordinary ventilation of a colliery. For it appeared the steam engine supplying the air for working the machine had a

cylinder of only 20 inches diameter and 3 feet stroke, and he considered it could not therefore send a sufficient quantity of air down the pit to produce any material effect upon the ventilation.

One great advantage might perhaps be anticipated from the use of the coal-cutting machine, namely that by this means the same quantity of coal could be got out of the pit without keeping open so great a length of working face; and it would be an important improvement to be able with the machine to keep open a much smaller extent of working face for the same yield of coal, because if double the quantity could be got from the same faces the interest on capital for the plant in the mine would be reduced one half. With this object there was at present a movement in South Wales for introducing the double-shift system practised in the north of England. so as to keep the pits at work the whole twenty-four hours, instead of letting them stand idle for sixteen hours, as was now the case; the double-shift if introduced was expected to produce a great saving in the cost of getting the coal, but thus far there had been a difficulty in introducing the plan.

The danger to the miners he thought would not be diminished by the use of the machine, as he believed the accidents occurring in working the coal did not generally arise from the coal breaking down upon the collier while holing underneath it, but generally from a fall of the roof outside the face of the coal. There was therefore as great risk of such an accident when a machine was used as in holing by hand labour.

The main consideration at present however, in reference to substituting a machine for hand labour in getting coal, was the small proportion of the whole work that was affected by the machine. If like a lathe or a planing machine it would do all or nearly all of the work, there could be no question it would be highly valuable; but he did not think the value was sufficient to justify its adoption so long as the economy attending it would affect only about one tenth of the work of the mine. Colliery owners had perhaps been thought too backward in the adoption of machinery for coal cutting, but it was necessary that the question should be considered commercially as well as mechanically; and having paid much attention to the

subject for many years, he was sorry he could not see that the use of a machine would be economical in the collieries with which he was connected; and he feared it would yet be a long time before machinery superseded hand labour generally for getting coal.

The CHAIRMAN observed that the waste of coal in holing by the machine was much less than by hand labour, amounting to only about 4 per cent. with the machine in comparison with 12 per cent. by hand labour, as stated in the paper; and he thought the saving of 8 per cent. was considerable enough to be reckoned as an important advantage in coal cutting by machinery.

Mr. W. MENELAUS said that in the South Wales district the small coal made by the pick in holing was not wasted, but only reduced in value as compared with the large coal; it would however be a great advantage to reduce the quantity of small coal made, and no doubt the machine would effect a saving in that respect.

Mr. W. FAIRBAIRN enquired what was the actual difference of temperature at the working faces in consequence of the discharge of the compressed air from the coal-cutting machine. No doubt the quantity of air discharged from the machine was very small in comparison with the total volume of air passing through the mine; but being delivered fresh and cold close to the working face, he thought it must prove beneficial to the men at work.

Mr. FERNIE remarked that the whole of the heat developed by the act of compressing the air at the surface of the ground became dissipated in the compressing cylinder and in the air receiver at the surface, the compressing pump being surrounded with a current of cold water for the purpose of carrying off the heat; and therefore the full effect was obtained of the expansion, in cooling the air discharged from the machine at the working face below the temperature of the external atmosphere outside the mine, producing consequently an important effect in cooling the temperature at the place where the men were working.

Mr. W. MENELAUS said he had used compressed air at the Dowlais collieries for working underground engines situated a mile or more from the compressing engine at the surface of the ground; but although the air discharged from the engines was so cold that the

exhaust ports frequently became stopped up with ice, the quantity of the air bore so small a proportion to the general current of ventilation that it produced no appreciable effect on the temperature in the mine. The air compressing engine was of much greater power than the one mentioned in the paper, the cylinder being 36 inches diameter with 6 feet stroke.

Mr. W. Firth stated that he had found by actual trial that when the machine was working at the usual rate of about 80 blows of the pick per minute, with the air at a pressure of 45 lbs. per square inch, the reduction in temperature in the neighbourhood of the machine at the working faces was about 4° Fahr., namely from about 56° to 52°. An estimate of the volume of air discharged from the machine in working showed that the quantity was not infinitesimal, but quite sufficient to produce a sensible effect upon the temperature and the ventilation at the working faces; for at the rate of 80 blows of the pick per minute, the pressure of the air being 3 atmospheres and the cylinder being $6\frac{1}{2}$ inches diameter with 10 inches stroke, the quantity of air delivered into the mine was 120 cubic feet per minute at the pressure of the atmosphere. This supply of fresh uncontaminated air close to the working faces was found practically to produce a most beneficial effect upon the ventilation in the neighbourhood of the machine.

Mr. C. E. Amos observed that the heat developed at the compressing pump, being all got rid of at once as previously explained, represented a corresponding amount of heat extracted from the mine in the neighbourhood of the machine on the expansion of the discharged air; and although the quantity of cold air discharged was small compared with the total quantity of air passing through the mine, yet it was so much lower in temperature that it must make a perceptible difference at the working faces, especially as the discharge took place close to the men.

Mr. S. Firth remarked that the practical effect of the cold air discharged from the machine was shown by the fact that the men working the machine or engaged near it were glad to keep their coats on; while at a neighbouring bank in the same pit, away from the machine, they would be found working with their shirts off. The cold was so great at the machine itself that there had been much

trouble at first with ice in the cylinder, and it had been necessary to add a stop cock at the bottom of the air receiver at the surface of the ground, in order to run out the water accumulated from the compressed air; this was done every morning before beginning to work with the machine.

They had had a great many difficulties to contend with for many years in endeavouring to apply machinery to coal cutting, but they had now succeeded in doing the entire holing at the Tingley Colliery with one machine, which was a proof that the practical difficulties in the application of the machine had been overcome. Any argument against the usefulness of the machine on the ground that it did not do the whole work of the colliery, but performed only a small portion of the work, seemed to him not to be valid; and if that objection had been allowed to prevail in other cases, mechanical improvements generally would not have progressed as they had done. He was quite satisfied to take success by instalments, without being disheartened at not being successful in all points at once; and the coal-cutting machine described in the paper had been designed solely for the purpose of performing the undercutting of the coal, which was now successfully accomplished by that means. He enquired what was the system of working the collieries in South Wales, and how it was that the holing formed so small a proportion as one tenth of the work, and what was the thickness of the seams of coal worked there.

Mr. W. Menelaus replied that the South Wales pits were worked mostly on the long-wall system with a single shift, leaving the pit standing idle often for sixteen hours; the thickness of the coal seams was from 9 feet down to $2\frac{1}{2}$ feet. The South Wales steam coal was of a very friable character, so that it was worked much more easily and rapidly by the pick in holing than a hard coal would be; and by leaving the pit standing idle for from twelve to sixteen hours, the coal was brought down by the pressure of the roof, without much labour to the colliers in holing. On account of these favourable circumstances the proportion of labour required for holing the coal was so greatly reduced that it did not amount to more than one tenth of the work of the mine. Although he had

for many years advocated the application of machinery to coal cutting, he did not yet see how this could be economically accomplished in the South Wales district by a machine which only performed so small a proportion of the work as the holing.

Mr. S. Firth remarked that it appeared the only objection raised to the introduction of coal-cutting machinery applied merely to the South Wales collieries, and in that case it was only because machinery was not necessary, owing to the unusually small proportion of work in holing required to be done for getting the coal. There were however many other coalfields where the holing formed a much larger proportion of the entire work, amounting to as much as half the whole work of the colliery in some instances; and to these cases the machine was decidedly applicable. In the north of England two of the pick machines had now been at work for three years, and he understood they had given entire satisfaction and had been found very advantageous. One object aimed at in the double-shift system was he presumed to have only half the number of men at work at a time for the same yield of coal, so that in the event of an explosion occurring only half the number of lives would be endangered; and by the use of the machine for doing the holing, this advantage was realised to a considerable extent, as all the men otherwise employed in holing were absent. It had also been shown in the paper that, by employing the machine, as much coal was now got from a bank of 18 yards length as from one of 48 yards length undercut by hand labour; and one consequence of this diminished area of workings required to be kept open when the holing was done by machine was that in laying out a new pit it was not necessary to drive more than half a mile of headings before beginning to get the coal for market at the full rate of working.

Mr. J. Warburton said he had had frequent opportunities of seeing the working of both of the coal-cutting machines described in the paper. From what he knew of the South Wales collieries and the very friable nature of the coal in that district, he thought the mere holing of the coal might safely be put down at not more than one tenth of the entire work. But in the midland counties and in South Yorkshire and other parts of the country, the coal was

much firmer and much more difficult to get; and in these districts the holing, all of which would be performed by the machine, amounted to fully one fourth of the entire work of the mine, so that the machine would be applicable with great advantage. In many cases indeed in the midland counties the holers formed a majority of the colliers, so that a machine doing all the holing would perform at least one half of the work in the mine. With regard to the machine not being adapted for cutting vertical slits in addition to undergoing the coal, there was of course no necessity at all for vertical cutting in the South Wales coalfield, where all that had to be done was to undergo the coal, and it then fell down of itself in the natural course while the pit was left idle; and in other districts also he thought it would be preferable to avoid the labour and waste of vertical cuts by working the long-wall system and carrying the holing to a greater depth in from the face, so as to be able to break the coal down without requiring vertical cutting. The statement made in the paper respecting the number of accidents occurring from the coal falling upon the men while occupied in holing was he regretted to say unfortunately too true; and as this danger would be greatly lessened by substituting the machine for hand labour, he thought it was quite right that the safety attending the use of the machine should be reckoned among its advantages.

Mr. G. Gilroy remarked that in the Lancashire and Cheshire district the colliery owners had been for some time anxiously endeavouring to meet with a successful machine for coal-cutting, and at the Ince Hall Collieries near Wigan he had been trying a machine for some length of time, but hitherto without success. Throughout that district as well as in Yorkshire and North Wales he thought it was very desirable that the use of machines for getting coal should if possible be established; and he was satisfied that a successful machine for holing alone, without making vertical cuts, would do at least one half the work of the colliers. The small proportion of the holing in the South Wales coalfield he considered was quite exceptional, and he believed was confined to that district.

With regard to the alleged improvement in the ventilation of a mine by the use of the coal-cutting machines worked by compressed

air, he thought too much credit was claimed for the machines in this respect. For although no doubt a considerable cooling effect was produced in the immediate neighbourhood of the machine, he had not found in the trials which he had made that any material improvement took place in the general ventilation of the mine, or any appreciable lowering of the general temperature. The danger also of accidents from the falling of the coal would not be prevented he thought in any great degree by the employment of machines for holing.

Mr. W. Firth said he had not been aware previously that nature ever did so much for the collier as appeared to be the case in South Wales, where it seemed the men had little to do beyond going into the pit and fetching out the coal already got for them by nature with only a small amount of labour for holing. Under such circumstances, however desirous the proprietors of a colliery might be to substitute machinery for hand labour, there was manifestly no scope for the employment of a machine with any material economy of working. In other coalfields however, such as those of Yorkshire, Lancashire, and Cheshire, great difficulties were experienced in getting the coal, the seams being often very thin and lying at a considerable inclination, the coal of hard quality, and the roof and floor bad; and in these districts therefore he thought there could be no question as to the great advantage of introducing coal-cutting machines.

Mr. Fernie observed that in introducing machinery for coal cutting it was quite possible the work might at first have to be done at a slight loss by the machine until the new mode of working was fully established, after which there could however be no doubt as to the gain that would ultimately result. Where a pit had been originally laid out on the long-wall system in a manner suitable to the application of a machine, there was no difficulty at all in substituting machinery for hand labour; and this was the case at the Tingley Colliery, where already the entire holing was done by the machine. At present indeed the pit was perhaps not being worked actually cheaper than by hand labour, owing to the circumstance that at the present rate of getting the coal there was

not a sufficient amount of work in holing to keep the machine fully occupied; but when a sufficient number of banks were opened to keep the machine always at work, there was no doubt that the large yield of coal then obtained by the aid of the machine would be got with only half the number of men that were required when the holing was done in the ordinary way by hand labour. Though at present it had not been possible to succeed in getting the entire work of the colliery done by machinery, that was no reason why the substitution of machinery should not be accepted for performing an important part of the work. The pick machine in use at Tingley Colliery was of very simple construction throughout, and was worked by an ordinary collier, who managed it entirely; no skilled mechanic was required to work it or keep it in order, as there was no complication in any of its parts.

Another point to be considered in connection with the use of machines was, what was to be done when much deeper mines had to be worked than at present. When the present coal seams were exhausted it would be necessary to go deeper, and the deeper pits would require better ventilation; and he thought hardly sufficient importance was attached to the advantage attending the use of machines worked by compressed air, in respect to their effect upon the ventilation at the working faces. The air that came out of the machine was not like the ordinary air which arrived at the working faces after traversing a long length of passages through other parts of the mine; but it was brought pure and fresh from above ground, free from all contamination, and was discharged from the machine cool and grateful to the men, and at the very spot where it was most needed and most acceptable. This appeared to him a practical advantage which would prove of great value, particularly in the working of deep pits.

Mr. W. Menelaus wished it to be understood that the difficulties which occurred to him in connection with the employment of machinery for coal cutting did not arise from any objections to the particular construction of either of the machines described in the paper, and he did not think that either of them could be considered at all complicated. With reference to their mode of action, he had

not had an opportunity yet of witnessing the working of the two machines, but the slotting principle appeared to him more consonant with other mechanical operations than a simple imitation of the action of the pick in hand labour.

Mr. W. Moor said that at the Hetton Colliery they had had two pick machines at work for six years, and had found them answer exceedingly well. They were driven by compressed air, and the effect of the cold produced by the discharge of the air from the machine was just what had been described, that ice was formed in the slide-valve chest; but this was obviated by preventing the accumulation of water there.

Mr. E. Williams thought it somewhat remarkable that the machine which had been in use for six years at Hetton had not yet made its way into any other of the numerous collieries in the neighbourhood. The object of the proprietors of collieries was to get the coal cheaper; and the existence of this machine at one pit for so long a time, without spreading to other collieries, led him to infer that there could not be any great saving in its use as compared with hand labour. He thought that the holing of the coal did not constitute a sufficiently large proportion of the work of a colliery for the substitution of machinery to be productive of any very material saving.

Mr. W. E. Marshall observed that the cost of undercutting the coal and the proportion which that operation bore to the whole work of the mine would vary according to the thickness of the seam of coal worked; and it was therefore to be expected that there should be considerable differences in the cost of getting in different districts, as the holing of a thick seam was done at a much smaller cost per ton of coal got than in the case of a thin seam. In regard to the statement that the entire holing of the coal at the Tingley Colliery was now done by machinery, he enquired what was the extent of the work done in holing at that colliery, as he thought that to do all the holing in a colliery of ordinary size would require several machines to be used. He asked further whether any risk had been observed from the pick striking fire in working, and whether the dust produced by the pick did not seriously affect the health of the

miners; and also whether the noise made by the exhaust air discharged from the machine was not a serious hindrance in the way of hearing the sounds of the creeping of the roof, which were the warnings to the men as to the safety of the workings. He himself took a great interest in the application of machinery to coal cutting, which he considered to be a subject of vast importance; and he had found many difficulties and prejudices to contend with in working machines underground, where it was not possible to watch every process with the same ease as in the case of machinery working by daylight and in workshops.

Mr. S. Firth replied that at the Tingley Colliery they had at present only sixteen banks open, of 50 yards length each; and as the holing of these was done by the machine at the rate of five banks per day in regular work, there was not at present full work for the machine. They were now however driving fifteen additional new banks to be worked by the same machine, and when these were opened, he intended to start a second machine also, as a precaution against any delay by accidental stoppage of the present machine. At this colliery no coal was now cut by hand labour, but the machine did the whole of the undergoing. As to the proportion which the holing constituted out of the entire cost of getting the coal, the cost of holing by hand labour at some of the other collieries in the neighbourhood was about 15*d.* per square yard of holing, and the cost of filling was 4*d.* per ton, and of breaking down about 2*d.* per ton; and as a ton of coal was about a cubic yard, taking the seam of coal worked to be about $3\frac{1}{2}$ feet thick, the cost of holing by hand labour would in these cases be more than three times that of filling, or fully half the entire cost of getting the coal.

In holing by the machine, the pick caused sparks to fly occasionally, but he had never found it necessary to squirt water into the groove for preventing danger from fire; and he had never had any ignition or explosion of gas from that cause, and did not expect ever to have any, because the draught was so great at the machine that any gas issuing from the coal was completely carried off by the air.

Mr. G. Gilroy said that, from his own experience with the coal-cutting machine which he had tried, working a pick like that used in hand labour, he did not think the dust arising from the working of the machine caused so much inconvenience to the men as in holing by hand, because they were not obliged to be so close to the work; and with regard to the liability of sparks being produced by the blows of the pick, he did not see that there was any greater risk with a pick worked by a machine than with the ordinary pick worked by hand. The difficulties which he had met with in endeavouring to adopt machinery for coal-cutting had been in applying a machine day by day to the ever varying conditions of a mine, even though the machine itself might be mechanically correct. One requirement which he thought essential to the practical success of a coal-cutting machine was that it should be very portable, so that a man or a man and a boy could readily move it 20 or 30 yards without a tramroad; for one of the difficulties which he had experienced in working a pick machine consisted in keeping the tramroads sufficiently level and the sleepers packed securely enough, so as to resist the blows of the machine and not be pushed away by them from the face of the coal; and the tramroad had to be kept level enough to ensure the pick cutting out a level groove. All this required great attention, and had formed an obstacle to the introduction of machinery; he hoped however that these difficulties would ultimately be got over.

Mr. H. Lawrence remarked that the Hetton Colliery was not the only one in the north of England where coal-cutting machines had been successfully adopted; for he had recently been down the Nedderton Colliery near Bedlington, Northumberland, and found that two hydraulic machines on the slotting principle had already been in use there for some time, and a third also was about to be put to work, which showed that the two previous ones must have proved advantageous. One consideration to be borne in mind in relation to getting coal by machinery was that there were very many narrow seams of coal, as yet unworked on account of their thinness, which, as coal became more and more valuable, it would be necessary to work. But if it were attempted to work by hand a seam of only 2 to

$2\frac{1}{2}$ feet thickness, the greater part of the coal would be broken up and wasted by the mere holing. If however a machine were employed to undercut in the shale at the bottom of the coal seam, the whole thickness of the seam would be obtained as valuable coal, and could thus be worked with profit. This was already being done at the Nedderton Colliery, where they were now working by the hydraulic machine a very narrow seam, only 2 ft. 6 ins. thick, which it would not pay to work by hand. In this case the heading in which the machine was working was not more than 3 ft. 6 ins. high, and the tubs for conveying the coal away were made to rest on the axles, leaving only just room enough for filling between the top of the tub and the roof. At that colliery the machines were kept at work all night with two or three men to attend them, and they undercut in the night as much coal as the colliers could break down and fill during the whole of the next day.

Mr. W. E. Marshall thought the machine working on the slotting principle had obviously an advantage in one respect over the pick machine, that it cut the groove to the full depth at one operation, whereas it appeared the pick machine had to go over the work a second time in order to complete the cut to the required depth. This involved the trouble and delay of bringing the machine back to the starting point, and he thought there might be some difficulty in getting the pick to strike correctly in the same groove in the second course. He enquired whether there was ever any trouble from the pick machine being thrown off the rails by the violence of the blows given with the pick.

Mr. Fernie replied that it occasionally happened that the pick machine got thrown off the rails in working, and this had occurred during the trial that he had made of the machine. It was however got on the rails and at work again in one minute, the collier having a belt round his waist from which a short chain was hooked to the machine, so that by straightening his back he easily lifted the machine on the rails again without any material loss of time. The slotting machine was of course very steady in working, being held down securely upon the rails by the upward pressure against the roof. The noise made by the discharge of the exhaust

air from the machines had not, he believed, been found any inconvenience; no doubt there was more dust than in using the ordinary pick, as the amount of work done was so much greater.

Mr. S. Firth said it had been the practice hitherto with the pick machine to do the holing in two courses, as described in the paper, first with the shorter pick, and afterwards with a long pick finishing the cut to the required depth, the object having been to avoid getting the pick continually choked in the groove by attempting to cut to the full depth in a single course. He had now however adopted a sort of double-headed pick, long enough to hole to the full depth of cut when it was required to cut a yard deep at one course over, and having the second head fixed to the arm of the pick at a shorter radius and shaped with a broader face than the cutting head; so that in the back stroke of the tool this second head swept the rubbish out of the groove and kept it clear. With this pick the holing was now done in a single course, and the rate of holing with it was 30 lineal yards per hour, undercutting to a depth of more than 3 feet in from the face.

Mr. T. Hawksley remarked that the question of the relative merits of hydraulic and pneumatic machines was a subject which he had had occasion to study under a great many aspects; and there were two considerations which led him to think that, as applied to getting coal, a pneumatic machine must ultimately be found superior to one worked by hydraulic power. In the first place, air when in motion was subject to very much less friction than water; and even when the air was compressed to three or four atmospheres he had found that the friction amounted to only 1-12th or 1-14th of that of water, in travelling through a tube of the same dimensions. The other consideration was that with a hydraulic machine there was the water to be got rid of; because as long as the machine was worked by a supply of water from the top of the pit, the water so sent down had all to be pumped up again, like the rest of the water in the mine, and there would consequently be a considerable loss of power. That loss would of course not be quite so serious if it could be managed to supply the water pressure to the machine by means of a steam engine worked at the bottom of the pit, because the water

would then be repeatedly used without being pumped up to the surface and sent down again, which was an operation attended with loss by friction and other inconveniences. These two points he thought were in favour of a pneumatic machine, as compared with one worked by hydraulic power. Moreover a machine worked by compressed air, according to the extent of its application, did certainly contribute to the ventilation of the pit, and to the cooling of the air in the immediate vicinity of the place where it was working. In the case of the Kremnitz machine for making artificial ice by the expansion of air previously compressed, which had now been in use for more than eight years, the water issuing with the jet of air was frozen instantaneously by the expansion of the discharged air, and issued from the machine in the form of pellets of ice, which were ejected with considerable force. Therefore, although there were some advantages of another kind in favour of water power, he was inclined to pneumatic machines as better and more convenient for such a purpose as coal cutting. He was also inclined to prefer a machine acting upon the slotting principle for undercutting the coal, which he thought was a more mechanical contrivance and appeared likely to work more advantageously than an attempt to imitate, perhaps somewhat imperfectly, the action of the ordinary pick wielded by the collier; and it would probably reduce a smaller proportion of the coal to powder, by reason of making rather narrower a slit. This was a point however which could only be decided by the actual circumstances of the working of the two descriptions of machine.

The Chairman moved a vote of thanks to Mr. Fernie for his paper which was passed, and also to Mr. Firth and Mr. Donisthorpe for the excellent arrangements which they had so kindly made for affording the members an opportunity of witnessing the working of the coal-cutting machines.

The Meeting was then adjourned to the following day. In the afternoon the Members visited various Iron works and Engineering works in Leeds and the neighbourhood, which were opened to their inspection during the days of the meeting.

The Adjourned Meeting of the Members was held at the Philosophical Hall, Leeds, on Wednesday, 29th July, 1868; William Fairbairn, Esq., Past-President, in the Chair.

The Chairman alluded to the recent munificent gift to the country by Mr. Whitworth of the sum of £100,000, for the establishment of thirty annual scholarships of £100 each, to be held by workmen going through a thorough course of scientific and artistic training; and he had great pleasure in moving the following resolution in recognition of Mr. Whitworth's munificence:—"That "this Meeting expresses the high sense it entertains of the eminent "service rendered to the country by the munificent gift of Mr. "Whitworth for the creation of scholarships in practical science "and mechanical art."

Mr. T. Hawksley, in seconding the resolution, said he was sure they all felt deeply indebted to Mr. Whitworth for this practical endeavour to promote a class of instruction which would prove of great advantage to the country; and in acknowledging his munificence, they desired to recognise not only the magnitude of the gift itself, but also the appreciation which it showed of the real wants of the present age, and of the demand that had arisen for a more thorough practical study of science and art.

The resolution being put to the Meeting was carried unanimously.

The following paper was then read:—

DESCRIPTION OF A TRAVELLING CRANE WORKED BY CLIP DRUM AND WIRE ROPE.

By Mr. JOHN FERNIE, of Leeds.

Few mechanical improvements have been so rapidly and so extensively adopted as the quick-rope Travelling Crane, introduced by Mr. Ramsbottom at the Crewe Works, a description of which was given by him to this Institution in 1864. During the short interval that has since elapsed, the extension of the application of this system has been so great, that at the present time there is scarcely a shop for the manufacture or repair of locomotive engines but has several of these cranes at work.

The Travelling Crane forming the subject of the present paper has been invented at the Steam Plough Works, Leeds, where there has been great experience in the manufacture and working of steel wire ropes; and the idea occurred that an improvement could be made by adopting a steel wire rope working with a clip drum, instead of a cotton rope acting by friction only; and that for out-door work, in quarries or over docks for shipbuilding, where a cotton rope would be subject to injury by exposure to the weather, a steel wire rope would be preferable. A case has indeed recently arisen where it would be impossible to make use of a cotton cord, the crane being employed in a large armour-plate mill for carrying away the plates on leaving the rolls; and the heat from such large masses of iron is so great that a cotton cord as usually applied would be quickly burnt up. For the same reason it has been found necessary in this instance that the man working the crane should be kept at a distance from the heat, and he is therefore stationed in a box at one end of the travelling frame, instead of being placed immediately over the work as usual.

The application of a steel wire rope and clip drum for communicating power formed the subject of a previous paper read before this Institution by the late Mr. John Fowler and Mr. David Greig on the application of steam power to the cultivation of the soil (see Proceedings Inst. M.E. 1865 page 55); and the crane now to be described is only a further adaptation of the same means for communicating power at varying distances from the prime mover.

This Crane is employed at the Steam Plough Works, Leeds, for lifting locomotive engines and other heavy work ranging from 15 tons downwards; it has a span of 40 feet, and traverses a length of 180 feet. The three different motions, for longitudinal traverse, cross traverse, and hoisting, are all derived from one endless steel wire rope, $\frac{3}{4}$ inch diameter, and weighing 2 lbs. per yard. This rope is driven at a speed of 4 miles an hour by means of a clip pulley fixed at one end of the shop, which is driven by belts and gearing from the engine working the shop. The rope extends the whole length of one side of the shop, going and returning on the same side at the level of the traveller, and passing round a loose pulley at the further end of the shop. The rope is entirely unsupported between the two ends of the shop, and is not strained tight, but hangs loose with only a slight tension, because the peculiar action of the clip pulley allows of the whole power being communicated to the rope by the grip of the pulley through half its circumference, even when the tail rope is entirely slack.

The construction of the crane is shown in Figs. 1 to 11, Plates 82 to 87. The clip pulley A, Fig. 1, fixed at the end of the shop, is speeded to drive the wire rope B B at the rate of 4 miles per hour, and lays hold of the rope with an amount of grip proportionate to the strain thrown upon the rope by the load, releasing it from its grasp when the rope has passed the centre line. The construction and fixing of the moveable jaws or clips round the circumference of the clip pulley is shown one third full size in Figs. 10 and 11, Plate 87. At one end of the travelling platform C of the crane is fixed another clip pulley D, Figs. 3 and 4, of the same size and construction, round which the same wire rope passes, making three quarters of a turn

round it. The rope then passes on to the further end of the shop, and round the grooved pulley E at that end, Figs. 1 and 3; this pulley is centred in a sliding frame provided with an adjusting screw G, for tightening up the rope to any tension required. It has not been found necessary to have any sliding weight attached to this frame, for variable tension of the rope; nor indeed has the original adjustment been altered since the crane was first put to work about two years ago. The wire rope has no slippers or carrying pulleys to support it, and is consequently free from the friction that accompanies their use; nor is it proposed to put any carrying pulleys for distances under 600 feet. The shop in which the present crane works is 180 feet long, and the rope hangs in a catenary curve through that distance, the deflection from a straight line being from 3 inches to 2 feet, according to the degree of tightening by the end pulley E.

The gearing for working the longitudinal traverse and the cross traverse is of the ordinary description, the motion being communicated from the clip pulley D on the traveller by means of friction clutches. The longitudinal traverse has a speed of 30 feet per minute, and the cross traverse 20 feet per minute.

The lifting gear consists of a very long cast-iron nut or screwed barrel H H, extending nearly the whole length of the traveller, as shown in the plan, Fig. 2, and to a larger scale in Figs. 5 and 6, Plate 85; and inside the barrel works a short screw I, Fig. 5, sliding on two feathers upon the long shaft J J, which is driven by a friction clutch from the clip pulley D on the traveller, so that by the revolution of the shaft the screw is traversed along within the barrel. The long driving shaft J is supported at intermediate points of its length by the two sliding brass steps K K, Figs. 5 and 7, sliding along freely within the barrel H, and kept apart from each other at the distance of half the length of the barrel by the long rod L; by this means the shaft J is never left unsupported for more than half of its length. The screwed barrel H is cast in two halves longitudinally, and bolted together, as shown in Fig. 6; and the pitch of the screw thread is $1\frac{3}{4}$ inch, the diameter being $6\frac{1}{2}$ inches.

One end of the hoisting chain being attached to the screw frame M, Fig. 5, the chain N passes along through the inside of the barrel H, round a pulley P, Fig. 2, at the further end of the traveller; then over a pulley on the cross-traversing carriage R, Figs. 8 and 9, down to the snatch-block S, and up again over a second pulley on the carriage R; and the end is attached to the nearer extremity of the traveller at T, Fig. 2. There is no reason however why an ordinary crab might not be used, worked by a shaft extending from end to end of the traveller; and that plan is adopted in a second crane now being erected at the Steam Plough Works, and also in the crane for the armour-plate mill previously referred to; but for heavy weights it is still considered that the long screwed barrel above described is preferable. The crane has two speeds for the lifting gear, one being at the rate of 6 feet per minute, and the other at the rate of 3 feet per minute; and at the latter speed the crane is calculated to lift 15 tons.

It is most desirable that all machinery of this kind should be kept constantly running, so as to be available for immediate use at any moment when required, without any delay for starting it to work; but inasmuch as the total time during which the crane is actually in use does not amount to more than about one hour out of ten, it is of special importance that the power employed to drive the rope when the crane is not in use should be reduced to as small an amount as possible. If a quick-running rope is employed, the absorption of power for keeping it in constant motion forms a large proportion of the total power required when lifting a load, and this is a loss which is always going on throughout the day; but when a slow speed of rope is employed, this constant loss is greatly reduced. The pull required to put the wire rope in motion when the crane is standing idle is 128 lbs. When lifting a load of 10 tons at the usual speed of 3 feet per minute, the additional pull upon the rope due to the load is 191 lbs., making the total pull 319 lbs.; and the horse power required with the wire rope is consequently 3·4 horse power with a load of 10 tons, and only 1·4 horse power when standing idle, these amounts being very much less than in the case of the quick-moving cord crane.

This crane has been in use at the Steam Plough Works for two years, and has been found to be easily and cheaply worked; and not the least of its recommendations is that it is almost noiseless. The original wire rope is still working, and appears at the present time practically as good as the day it was started.

Mr. W. Clay observed that in the use of cranes driven by a quick-running cotton cord he had found it impossible during the recent cotton famine to get cotton cords that would stand for any considerable length of time, as the only cord that could then be obtained for the purpose was made of common Surat cotton, which was not good enough to stand the work. Under these circumstances he had got over the difficulty by using a hide rope, which was found to last for about eighteen months without any serious wear and tear. Although therefore the wire rope now described might be a great improvement over the ordinary cotton cord, still as there were already so many cranes at work driven by the quick-running cotton cord, it might be useful to know that a hide rope could be employed for the same cranes, and would last longer than the cotton cord.

Mr. E. A. Cowper enquired whether any trial had been made of running a light steel wire rope at the same speed as the cotton cord, and so using it to work one of the cranes hitherto driven by the cotton cord. In the crane now described he thought the lifting speeds of 3 and 6 feet per minute seemed rather slow in comparison with the longitudinal and cross traversing motions of 30 and 20 feet per minute; and the latter were perhaps rather faster than usual in such cases.

Mr. Fernie believed that in engineering shops generally the speed of 6 feet per minute for hoisting light loads would be considered amply sufficient; and for heavy work 2 feet or even

$1\frac{1}{2}$ feet per minute was enough, and in the 25 ton traversing crane at the Crewe Works the lowest speed of lifting was not more than $1\frac{1}{2}$ feet per minute. With regard to the use of a light steel wire rope in place of the present cotton cord, he did not think it would be possible to run even the lightest wire rope at anything like the speed of 40 or 60 miles an hour at which the cotton cord was driven, because the much greater weight of the steel rope would tell so seriously at a high speed, and the frequent bends would greatly reduce its durability; the important advantage in the cotton cord, which allowed of its being run at such a high speed, was its lightness.

Mr. D. Greig said they had now had considerable experience at the Steam Plough Works in driving cranes with both cotton and wire ropes. They had used one of the light rope cranes for four years, and had found it of great advantage as compared with previous modes of working cranes; but the cost of working and the power required to keep the cord constantly running at the high speed were so great, as well as the wear and tear, that they had been led to look for some other mode of driving, as that plan of crane was found so useful that they wished to retain it. The experience gained in the successful use of steel wire ropes for steam ploughing machinery suggested the adaptation of the same mode of driving for the crane; and the result had been that the crane described in the paper had now been in regular work for two years, during which time it had not cost 25*s*. for keeping it in repair. With the light cotton ropes running at a very high speed he understood it was the general experience that they were found difficult to keep in repair; and the slow moving rope was not only less expensive in this respect, but also had the advantage of giving the same power for lifting without costing nearly so much for the power for driving the rope continuously at a very high speed during all the time that the crane was standing idle. As the crane was required to be always ready for work at a moment's notice, without the delay of having to send men aloft to work the crabs of a hand crane, it was necessary for the rope to be kept constantly running; nor was it practicable to economise the power in the case of the quick-running rope, by

stopping it at the times when the crane was not in use, because in starting it again the length of time required for getting up the high speed was as much as five minutes. Considerable difficulties had been met with at first in adapting the wire rope and clip drum to work the cranes; but these had now been successfully overcome, and in the course of a few months there would be several more of the wire-rope cranes at work in other engineering shops. At his own works the use of the wire-rope crane in the erecting shop had been attended with a very great saving in the expense of lifting all descriptions of work in the shop. To work the cranes by a light steel rope driven at the same speed as the cotton cord would be quite impracticable, on account of the weight of the steel rope and the number of bends it would have to make round pulleys of small diameter. The speed at which the wire rope was driven had nothing to do with the speed of lifting, the latter being previously determined by the proportions of the gearing, so as to give two speeds for lifting, 3 feet and 6 feet per minute, with a constant speed of 4 miles an hour for the rope; and the only effect of changing from the lower to the higher speed in lifting was to double the strain on the rope, without requiring the speed of the rope to be altered.

Mr. E. A. Cowper enquired what was the actual strain upon the wire rope at the two speeds of lifting.

Mr. D. Greig replied that in lifting loads of 10 tons and 15 tons at the usual speed of 3 feet per minute the strain upon the rope was from 3 to 4 cwts.; and even if the same loads were lifted at the higher speed of 6 feet per minute, the strain on the rope would not exceed $4\frac{1}{2}$ to $6\frac{1}{2}$ cwts. A rope of that size however, $\frac{3}{4}$ inch diameter, would safely bear a pull of 15 cwts. in steam ploughing machinery. The main object in using the wire rope for working the crane was to run the rope as slow as possible, requiring of course a corresponding increase of strain upon the rope; and the limit to the strain that could be put upon the rope would be the amount of adhesion of the carrying wheels of the traveller upon the rails, so that the crane should not only be able to stand stationary against the pull of the rope, but should also be capable of travelling in the opposite direction to the pull.

Mr. C. W. Siemens mentioned that at the Paris Exhibition in the previous year a plan had been shown of transmitting power to a great distance by means of a steel wire rope driven at a very high speed and running over large pulleys; and this plan had been employed in the mountainous districts of France and Switzerland for transmitting the power from a water wheel or turbine to a distance of half a mile or more up a mountain. There was less wear in this case he understood than was usually experienced in the working of wire ropes, probably owing to the circumstance that the distance travelled by the rope without any bends was so great, the bends being perhaps not more than one at each end of the entire distance. The rope was not driven by a clip drum, but by pulleys of $6\frac{1}{2}$ feet diameter; and the intermediate carrying pulleys were also of large diameter. The speed of the rope was very great, but the strain upon it was small because of the speed; and he had been informed it was found to perform the work exceedingly well, transmitting a large amount of power.

Mr. E. A. Cowper thought in the case referred to there must be a considerable amount of sag in the rope between the carrying pulleys, as there was not a heavy pull upon it to keep it up.

Mr. H. Chapman mentioned that the quick-running wire rope shown at work at the Paris Exhibition on Hirn's plan had broken shortly before the Exhibition closed; it had been at work about seven months, driving a centrifugal pump of about 25 horse power at a distance of 500 feet, the rope being rather less than $\frac{1}{3}$ inch diameter.

Mr. Fernie observed that in the crane now described, driven by a wire rope running at a slow speed, the main feature was the application of the clip pulley for driving the rope; and the important practical advantage attending the clip drum was that it did away with the sawing action of the rope in the ordinary V groove of a pulley, the clips laying hold of the rope with an amount of grip proportionate to the pull upon the rope, and holding it absolutely fast at the moment, and afterwards completely releasing it from their grasp as soon as it arrived at the point where it was a tangent to the pulley. By this means any power that was desired

could be transmitted by the clip pulley, without involving either the loss from friction or the wear and tear of rope attending the use of the ordinary grooved pulleys. Another advantage of the new plan was the low speed at which the wire rope had to be driven, in consequence of which the power required for driving it was only $1\frac{1}{2}$ horse power when the crane was standing idle, and $3\frac{1}{2}$ horse power in lifting a load of 10 tons at 3 feet per minute, the rope running at a speed of only 4 miles an hour. From experiments made with the previous crane at the Steam Plough Works, driven by the cotton cord running at 40 miles an hour, he had found that the power expended in driving the cord while the crane was standing amounted to as much as 12 horse power, and to 14 horse power when lifting a load of 10 tons at 3 feet per minute. This amount of driving power seemed so disproportionately great as to lead to the supposition that the crane must have been of defective construction in some respects; but even supposing that were the case, he was satisfied the quick-running cord absorbed under favourable circumstances at least four times as much driving power as the slow wire rope. As a workshop crane was required to be always ready for use, it was important that it should be kept in readiness with the smallest constant expenditure of power during the time it was standing idle; and this was satisfactorily accomplished in the wire-rope crane, by keeping the rope always going at the slow speed.

Mr. D. Greig said he had kept an account of the time during which the crane was in actual use, and had found it did not average more than one hour in each day, as so much time was consumed in the intervals between lifting, traversing, lowering, and fixing the work moved by the crane; but the rope had to be kept going continuously during the whole time, in order that the power might be ready for instant use whenever required.

Mr. B. Walker said he had one of the quick-running cranes in use at his own works and had also made several of them, and he did not think the power required for driving the cotton cord was so great as had been mentioned; he considered there must have been something defective causing extra friction in the crane which was found to absorb so large an amount of driving power, as the pull upon the

cord required for lifting the load alone was only about 1 lb. per ton of load when the cord was run at 60 miles per hour. He had also made one of the wire-rope cranes for Woolwich arsenal, in which the rope was driven at 6 miles an hour under a constant pull of 10 cwts.; and although it was certainly found to take less power for driving than the quick crane, he did not think the difference was so much as one in four, and he doubted whether the quick cord took more than twice as much power as the slow wire rope. As regarded the durability of the cord, there was no doubt that the quick crane was troublesome, notwithstanding that the wear and tear had been considerably reduced by taking care to diminish the friction as far as possible, by employing well-made pulleys and having as few bends as possible in the cord. But at the Crewe Works he understood one of the cotton cords had now been at work for seven months and was still in use; and the quick-running cranes employed there had been found so satisfactory that it had not been considered desirable to change to any other plan. He thought however, if the wire rope was found to be durable, that the slow-going wire-rope crane would become more general, because it did not require such good workmanship as was necessary in the high-speed crane.

Mr. C. E. Amos remarked that he had seen the working of the wire-rope crane at the Steam Plough Works and could fully endorse what had been stated as to its advantages; it appeared practically a very useful machine, and he thought the principle of using the wire rope running at a slow speed was the correct one. He was certainly surprised at the very great amount of power required in the quick crane to drive the cotton cord at 40 miles an hour, and thought there must be some undue friction in that case, as the crane should not take anything like so much power for merely overcoming the friction. As to the durability of the cotton cord, if it did not last much more than seven months, he thought that would be a serious objection to the quick-running crane; and in many engineering shops he considered it might then be even better to return to hand cranes, than to be liable to a breakage of the driving cord occurring perhaps at a time when the crane might happen to be most wanted for a press of work.

Mr. F. J. Bramwell observed that, although the power necessary for driving the quick-running cord appeared at first sight excessive, it must be borne in mind that, with the very high speed which was employed, a very small increase in the constant pull upon the cord soon mounted up to a large power; for at a speed of 40 miles an hour the pull upon the cord corresponding to a power of 1 horse power was no more than about 10 lbs. If therefore the pulleys of the crane were at all out of order, the small extra friction thereby occasioned would be sufficient at that high speed to account for a considerable increase in the driving power.

Mr. E. H. Carbutt thought the old plan of driving the crane by means of a shaft of square section running the whole length of the shop was preferable to the quick cord, because the power required to keep the shaft in motion while the crane was standing was altogether insignificant. A crane on that plan had been in use at his works for ten years, without any breakage of the driving shaft, and without any expense for repairs beyond ordinary wear and tear.

Mr. E. Reynolds suggested that one important source of friction in the quick-running cranes might be the worm and wormwheel employed for working the crab, the rubbing surfaces being made at such an inclination that the load upon the crab would stand in any position without running down, though no friction break was used; and he remembered it had been mentioned in the former description of the cranes at the Crewe Works, in which a wormwheel was employed, that a load on the crab, which would be equal to only 6 lbs. pull at the circumference of the driving pulley, was found to require as much as 17 lbs. to start it in lifting, showing that 11 lbs. or nearly double the theoretical power was absorbed in merely overcoming the friction of the worm when standing. Although arrangements of this class were sometimes very convenient, it should be remembered that any machine in which the friction was sufficient to sustain the load, and to check it if descending, must lose or consume in friction at least one half the power employed in hoisting.

Mr. B. Walker said that, with regard to the loss of power occasioned by the friction of the worms in the quick-running cranes, they had made several of the cranes lately without the worms, the

chain barrel of the crab being driven by spur gearing instead of the wormwheel; and in those cases the power required for working the crane was found to be considerably less than with the worms.

The CHAIRMAN considered the important feature in the wire-rope crane now described was undoubtedly the clip pulley, by which the application of the wire rope driven at so slow a speed had been rendered practicable; and it was this beautiful invention which had led to such successful results in the employment of wire ropes for the purposes of steam ploughing and cultivation. In the quick-running crane he thought there must certainly have been something wrong to require so great an amount of power as had been mentioned for working the crane; but he considered there could be no question as to the saving of power that would be effected in the present plan with the use of the clip pulley, by running the driving rope at a slow speed.

He proposed a vote of thanks to Mr. Fernie for his paper, which was passed.

The following paper was then read:—

Fig. 1.

Watt's Liberating Gear.

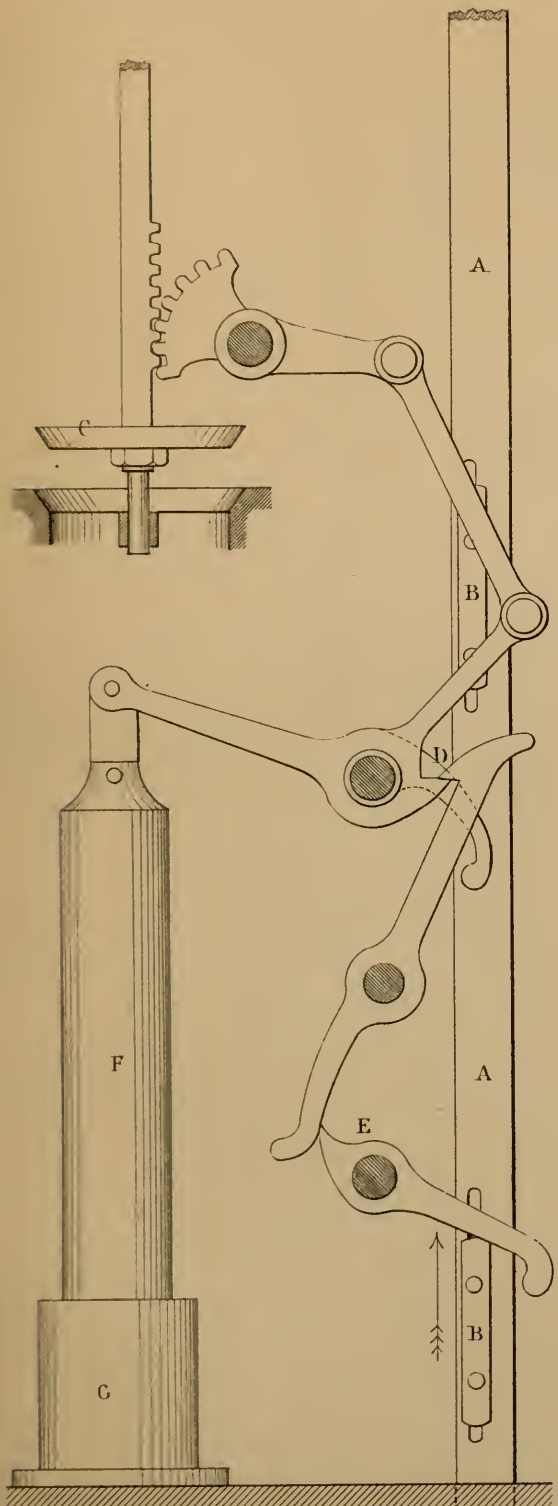
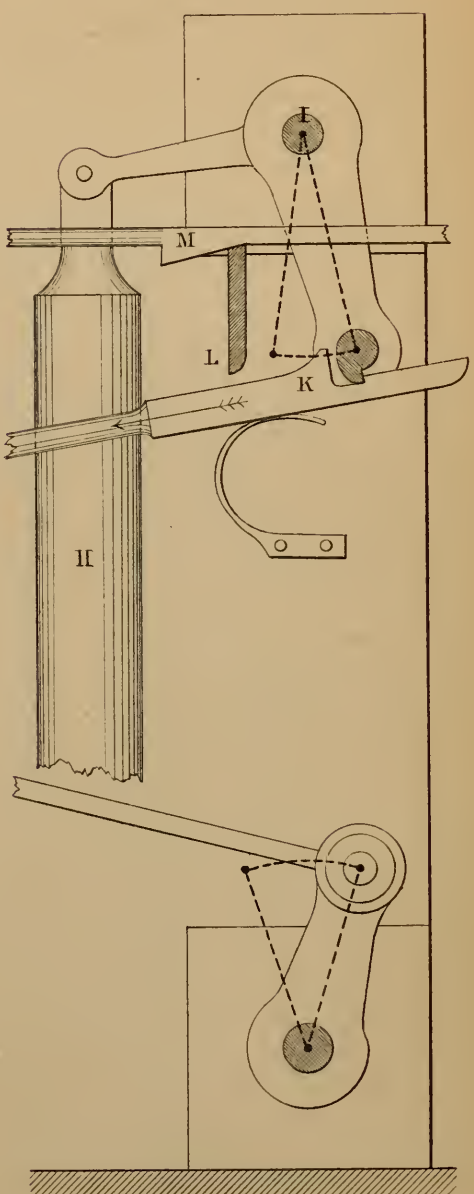


Fig. 2.

Corliss

Original Liberating Gear.



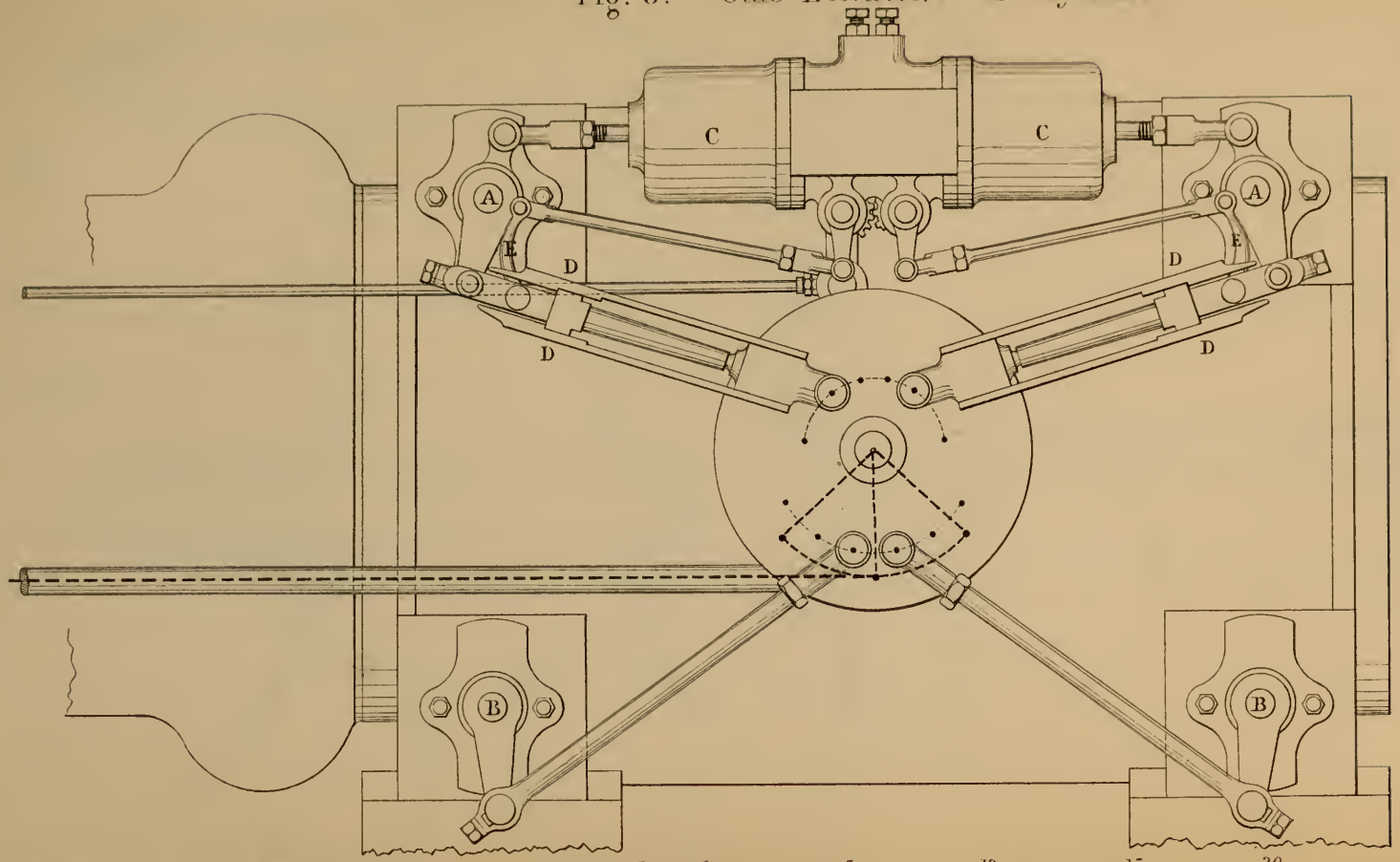
(Proceedings Inst. M. E. 1868.)

Scale 1/8 th

CORLISS ENGINE.

Woolwich.

Fig. 3. *Side Elevation of Cylinder.*



(Proceedings Inst. M. E. 1868.)

Scale 1/8th

0 5 10 15 20 25 30 Inches.

Woolwich.

Fig. 4. *Transverse Section of Cylinder.*

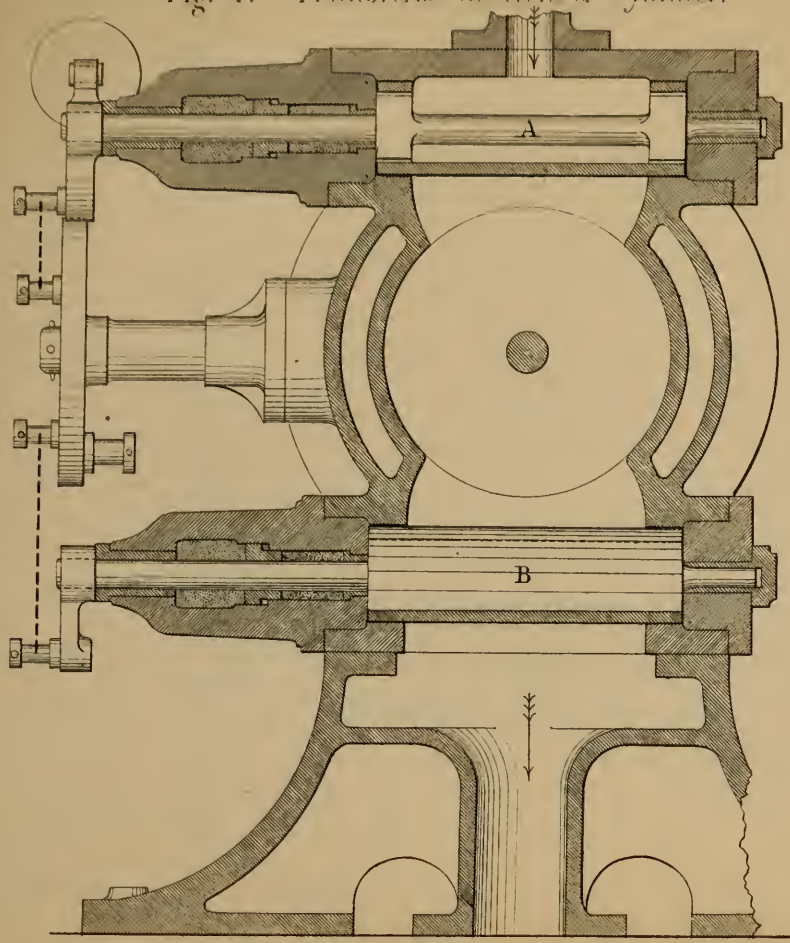
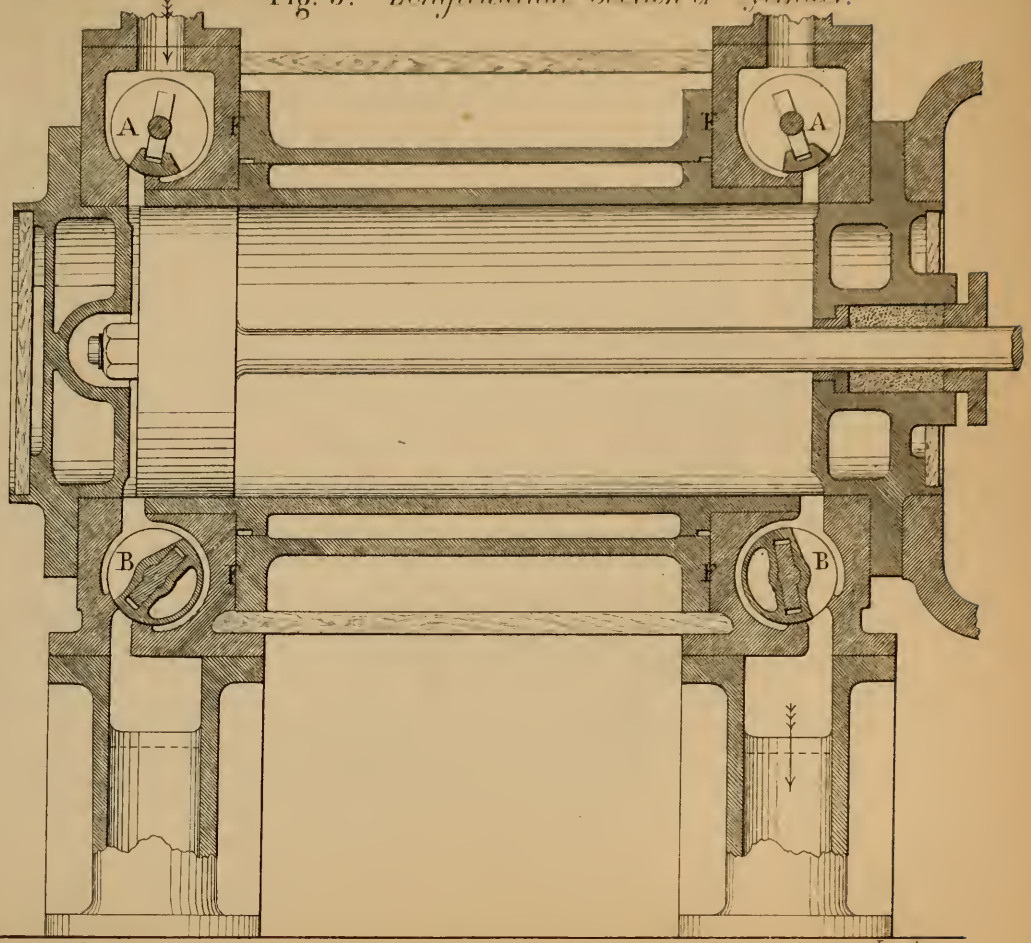


Fig. 5. *Longitudinal Section of Cylinder.*



(Proceedings Inst. M. E. 1868.)

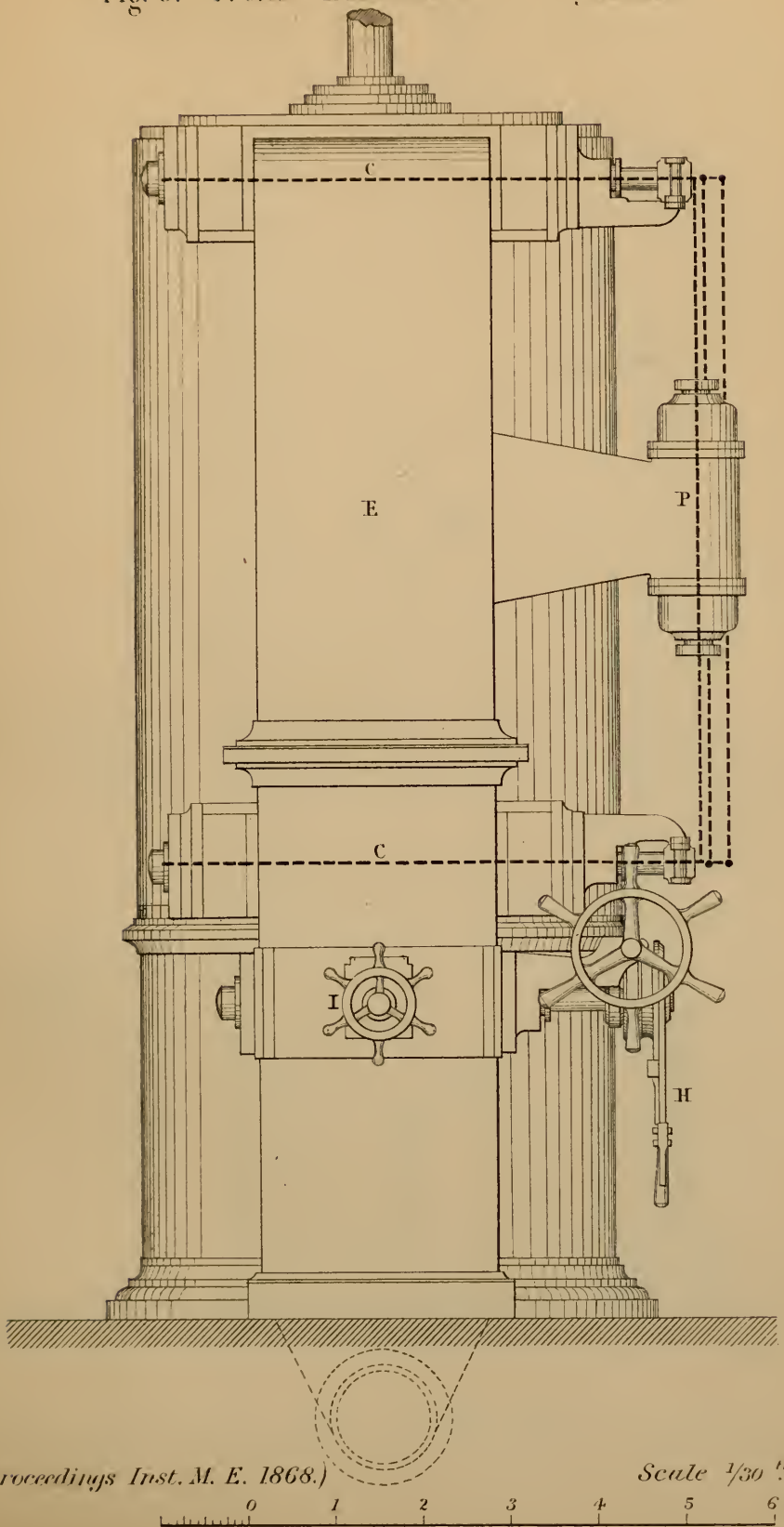
Scale 1/10th 0 5 10 15 20 25 30 *Inches.*

CORLISS ENGINE.

Plate 21.

Saltaire.

Fig. 6. *Front Elevation of Cylinder.*



(Proceedings Inst. M. E. 1868.)

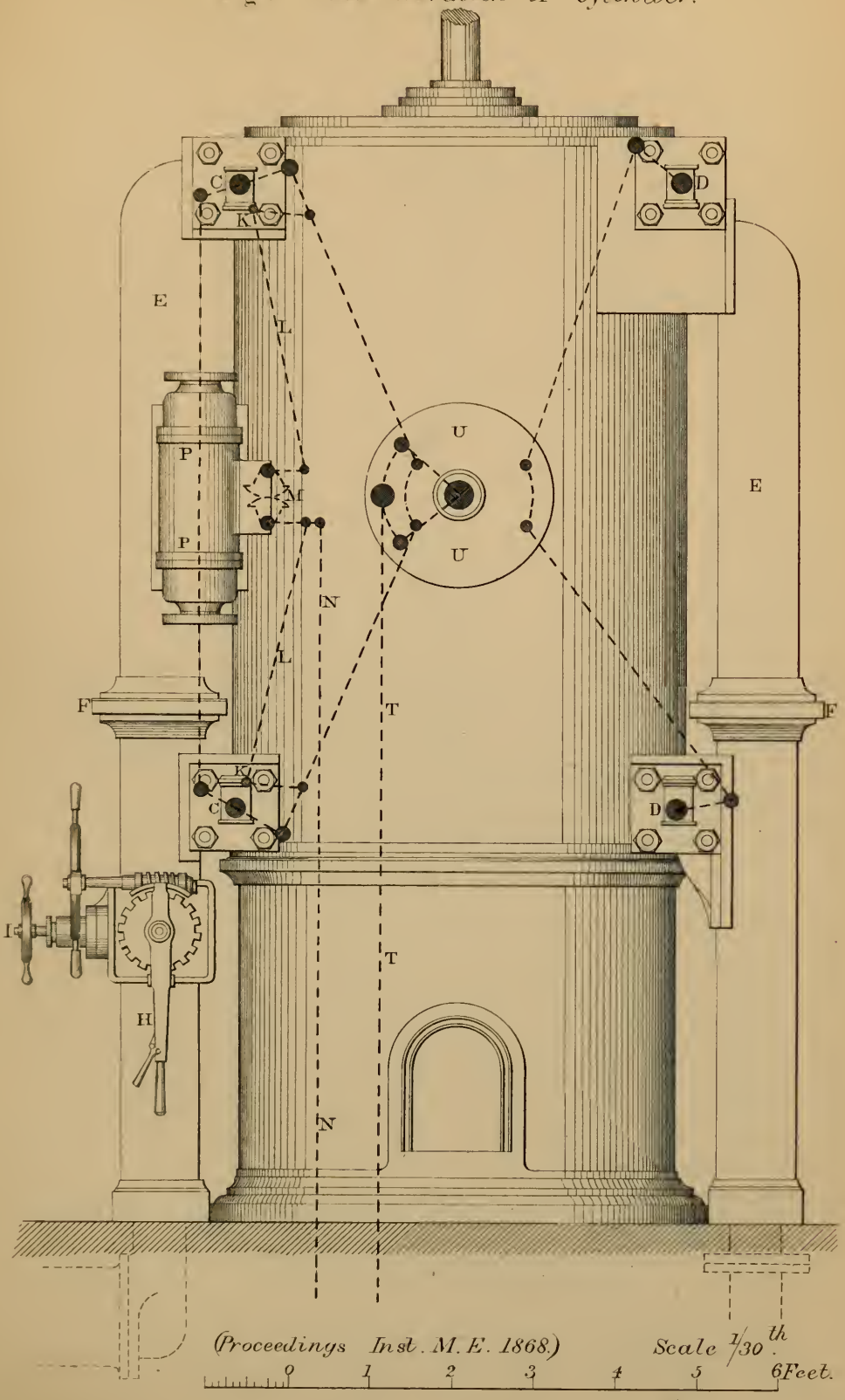
Scale 1/30th.

0 1 2 3 4 5 6 Feet.

CORLISS ENGINE. *Plate 92.*

Saltaire.

Fig. 7. *Side Elevation of Cylinder.*

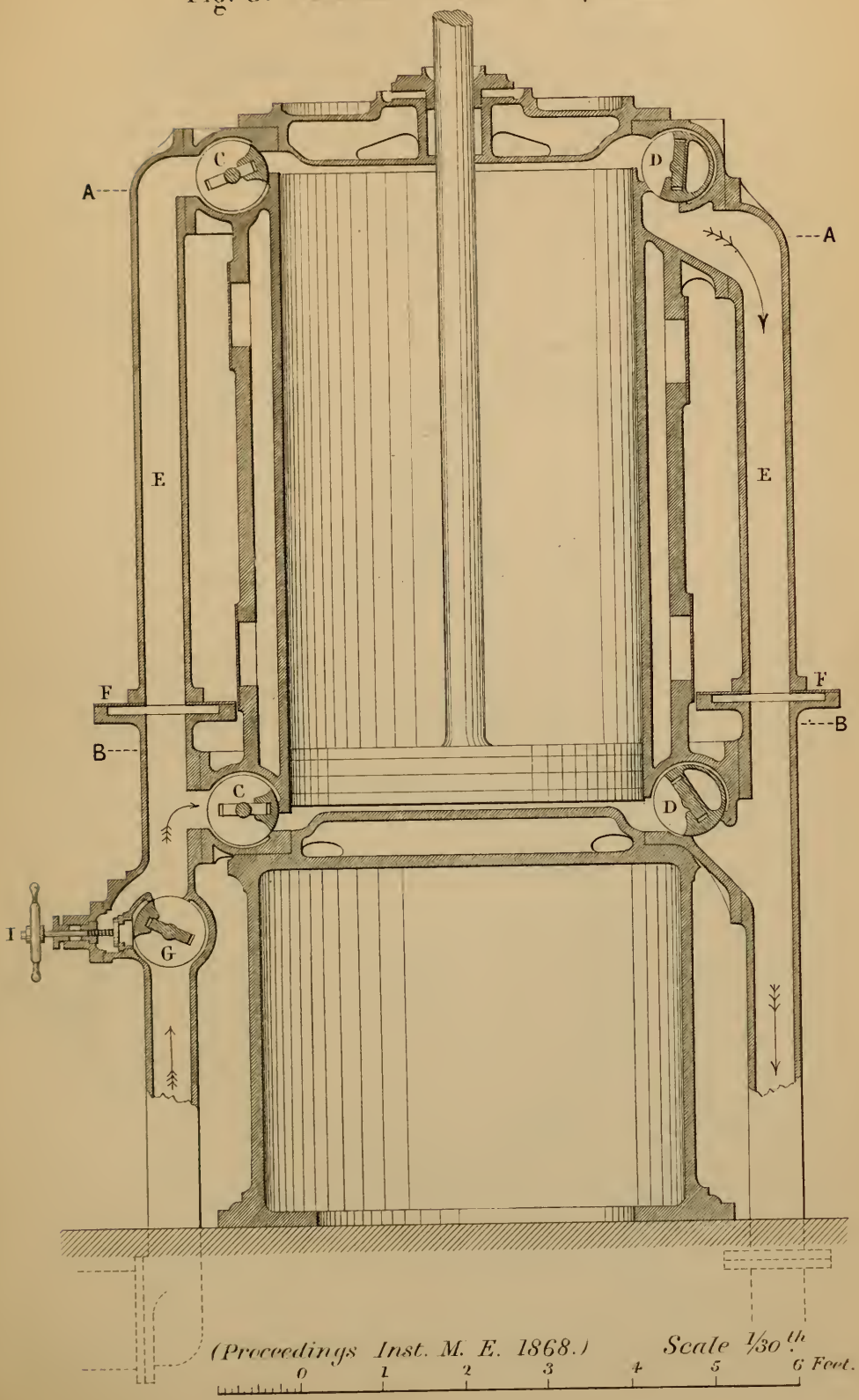


CORLISS ENGINE.

Plate 93.

Saltaire.

Fig. 8. *Vertical Section of Cylinder.*



Saltaire.

Fig. 9. *Plan of Cylinder at* AA. *(Fig 8.)*

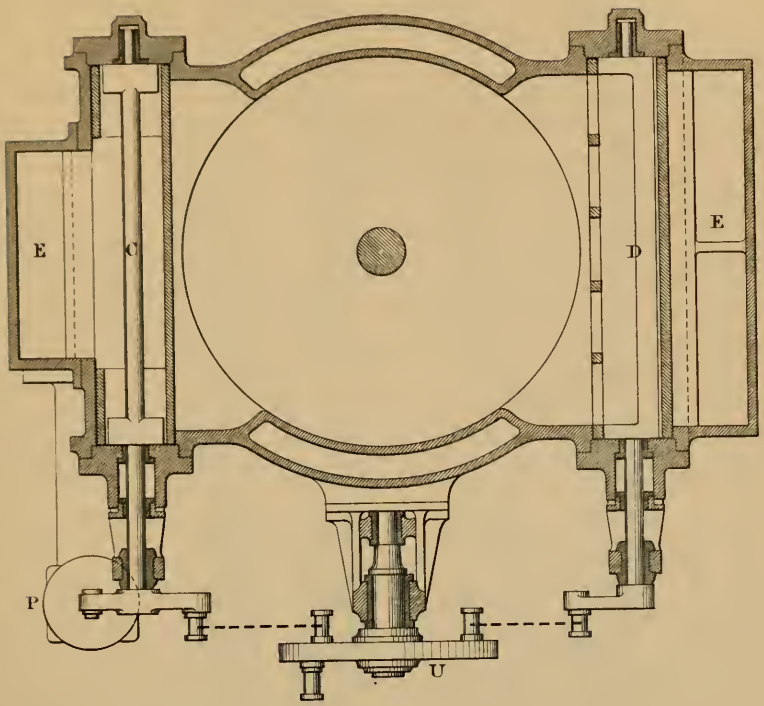
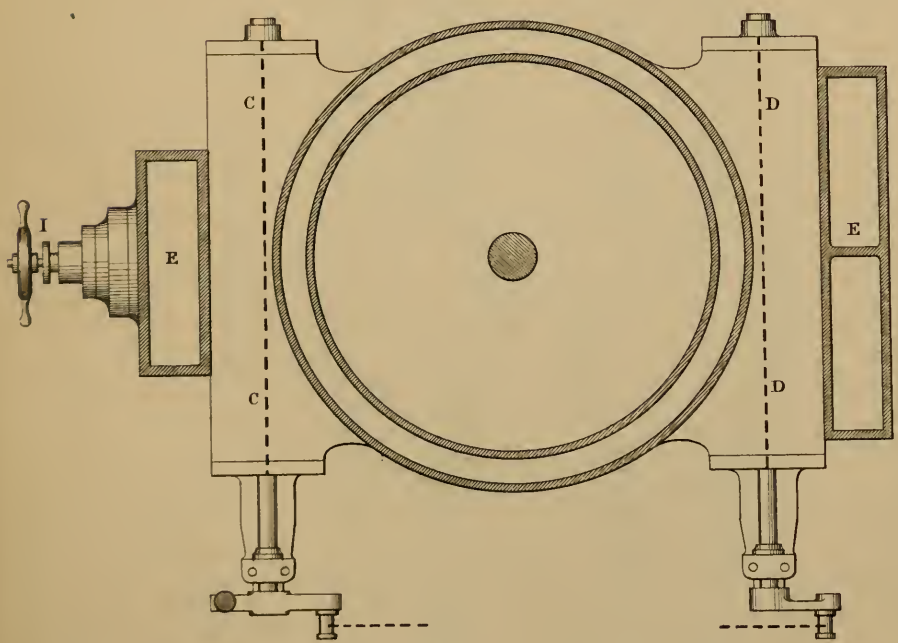


Fig. 10. *Plan of Cylinder at* BB. *(Fig. 8.)*



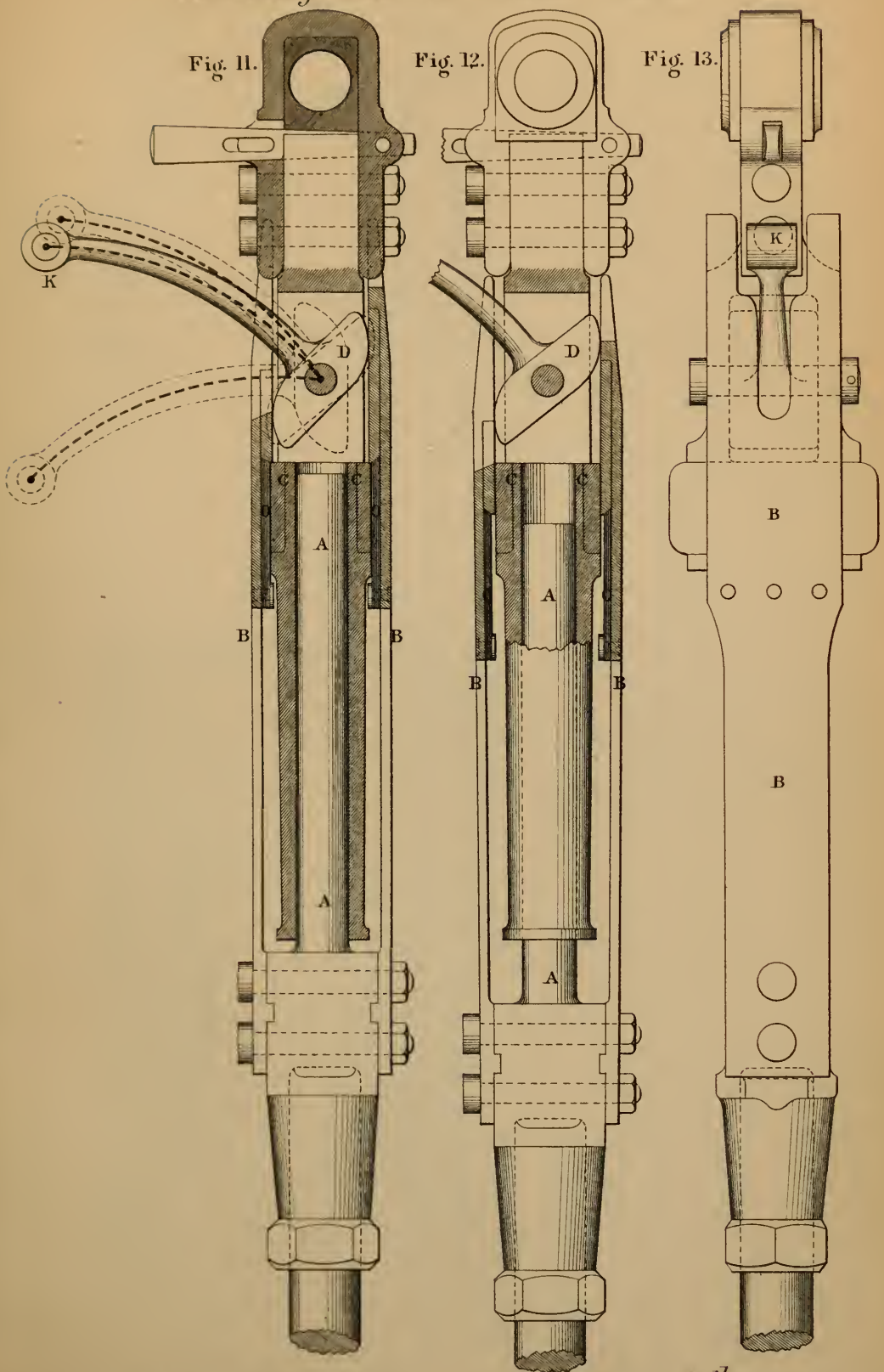
(Proceedings Inst. M. E. 1868.) *Scale* 1/30th

0 1 2 3 4 5 6 Feet.

CORLISS ENGINE. *Plate 95.*

Saltaire.

Liberating Gear for Steam Valves.



(Proceedings Inst. M. E. 1868.)

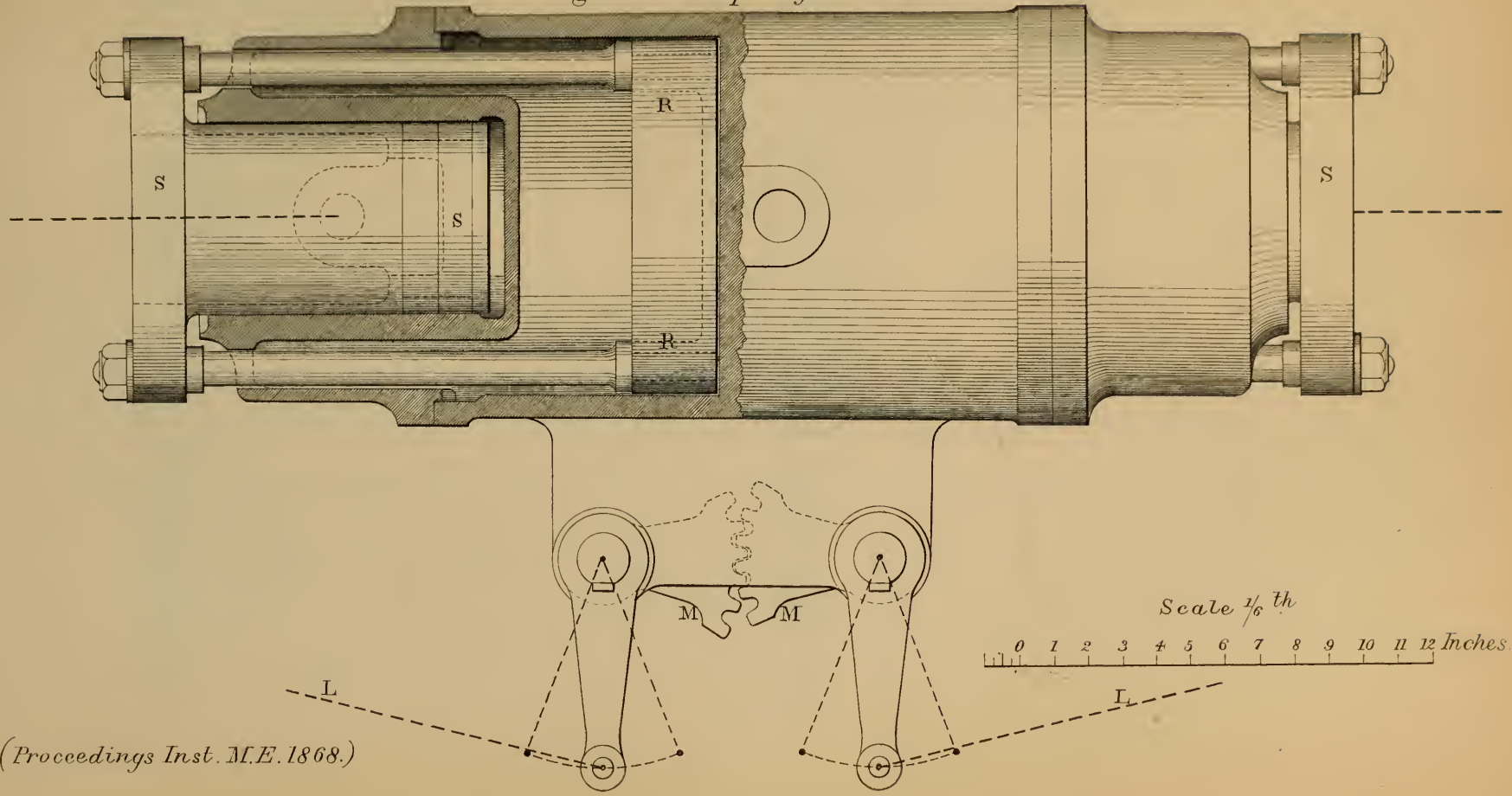
Scale 1/5th

0 5 10 15 Inches.

CORLISS ENGINE.

Saltaire.

Fig. 14. *Air-Spring Dash-Pot.*



(*Proceedings Inst. M.E. 1868.*)

CORLISS ENGINE. *Plate 97.*

Indicator Diagrams from Saltaire Engines.

Cylinder 50 ins. diam.r, 7 ft. stroke.

30 Revolutions per minute.

Speed of Piston 420 feet per minute.

Fig. 15. *Steam cut off at* 25 *and* 15 *per cent.*

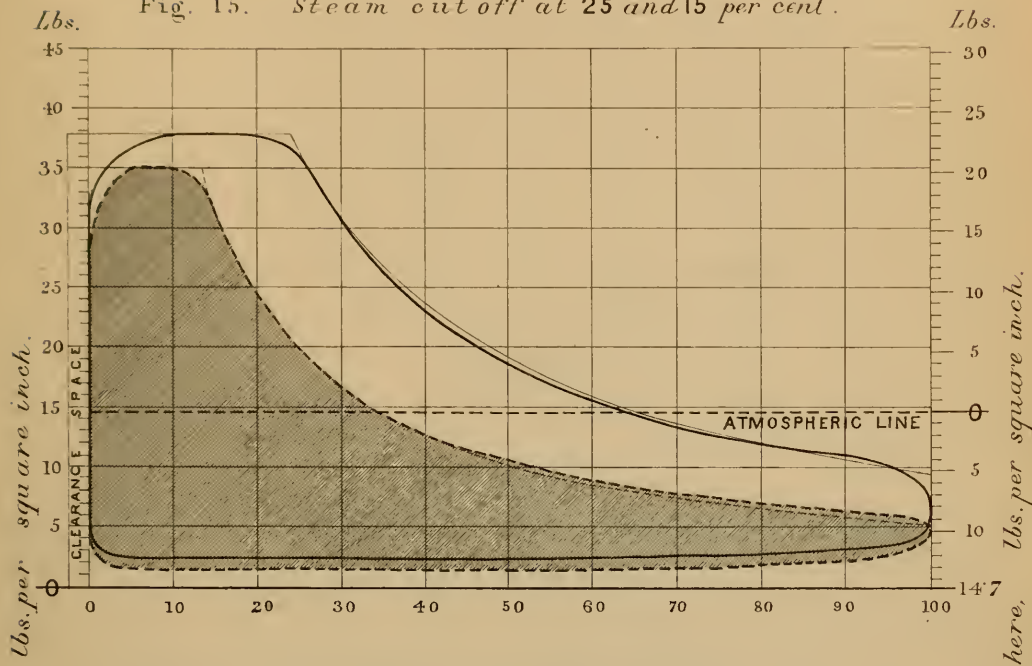
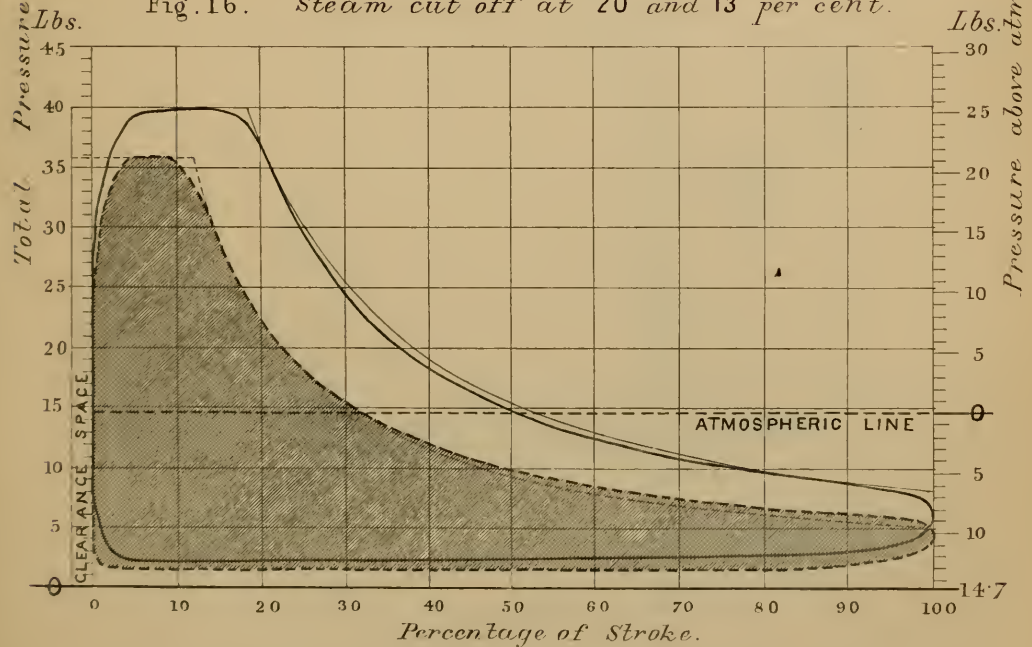


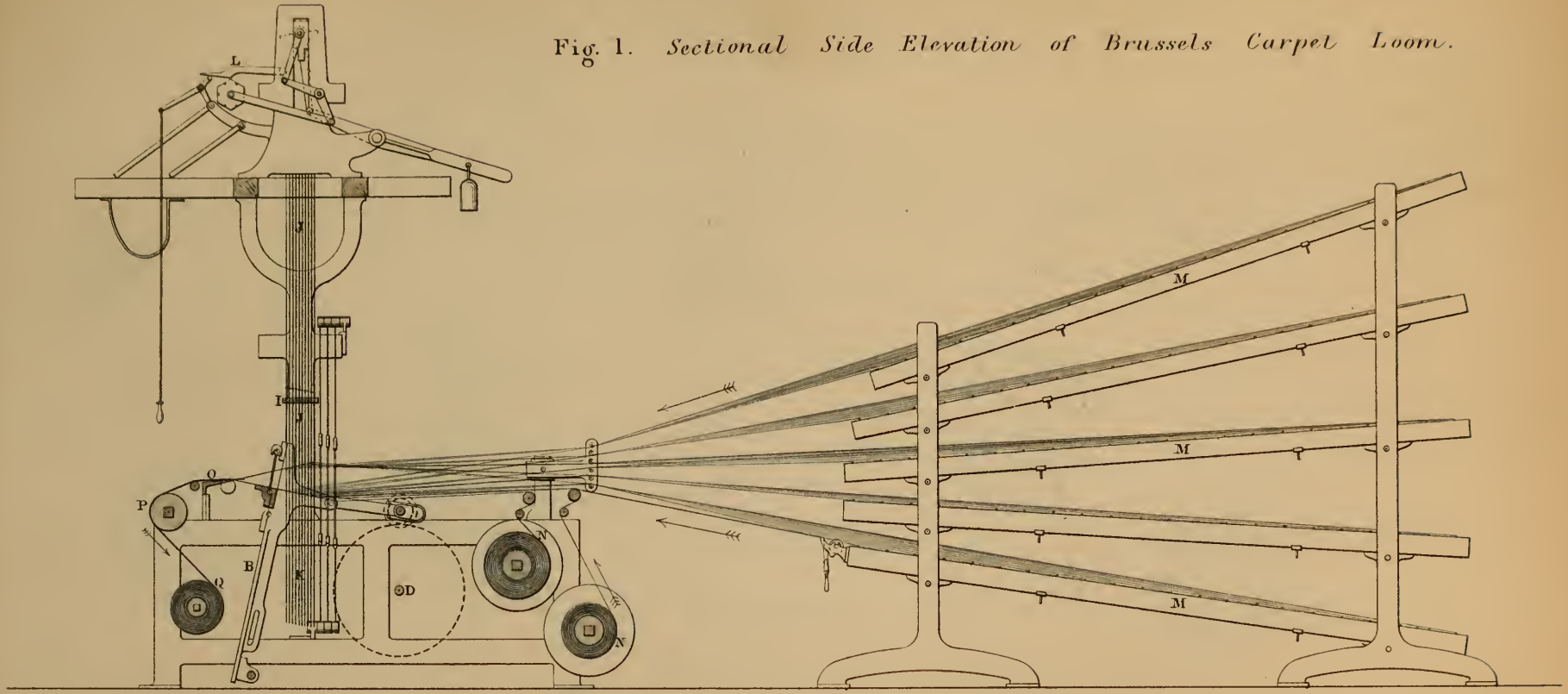
Fig. 16. *Steam cut off at* 20 *and* 13 *per cent.*



The fine lines show the theoretical true expansion curves.

(Proceedings Inst. M.E. 1868.)

Fig. 1. *Sectional Side Elevation of Brussels Carpet Loom.*



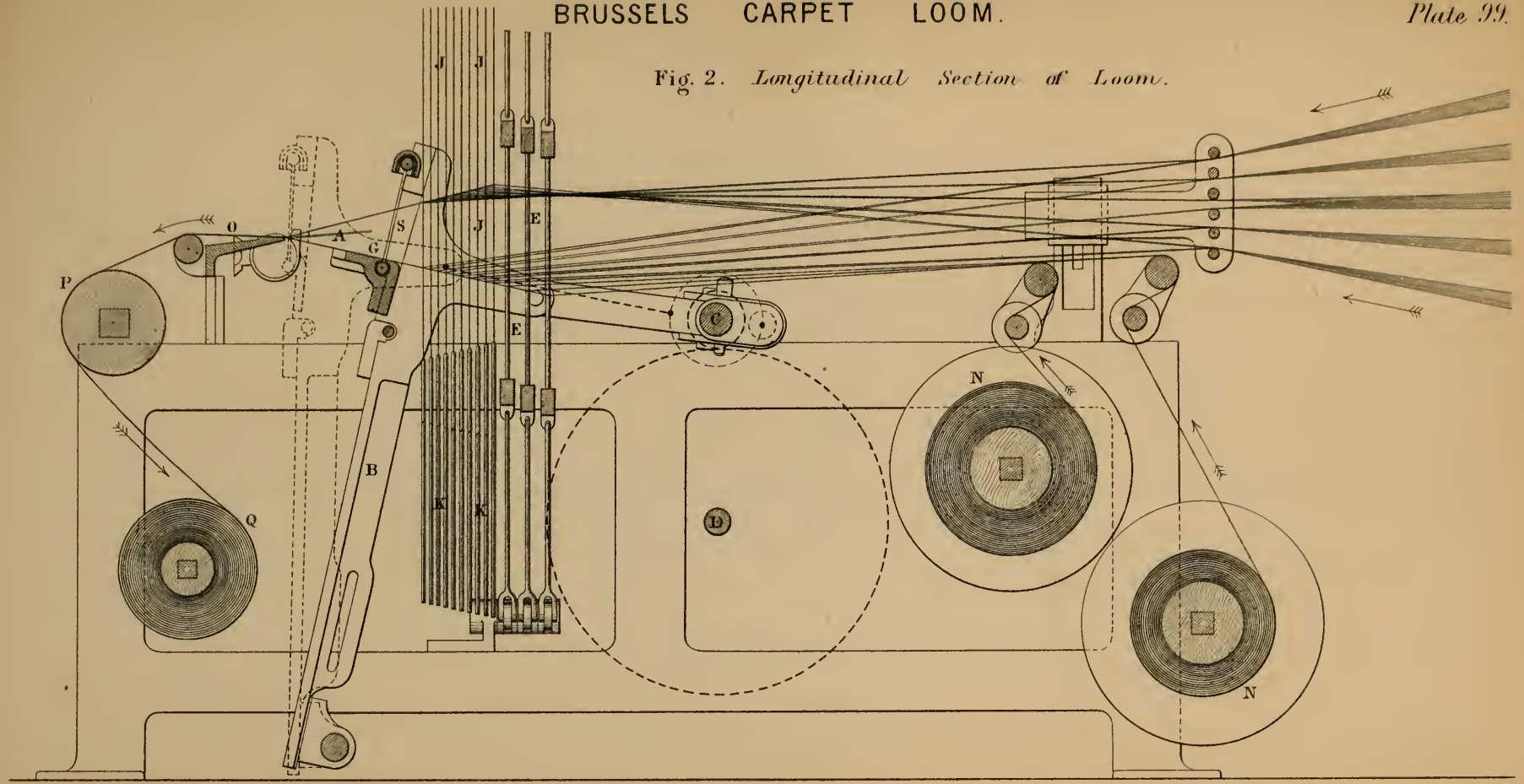
(Proceedings Inst. M.E. 1868.)

Scale 1/40th

0 1 2 3 4 5 6 7 8 9 10 Feet.

BRUSSELS CARPET LOOM.

Fig. 2. *Longitudinal Section of Loom.*

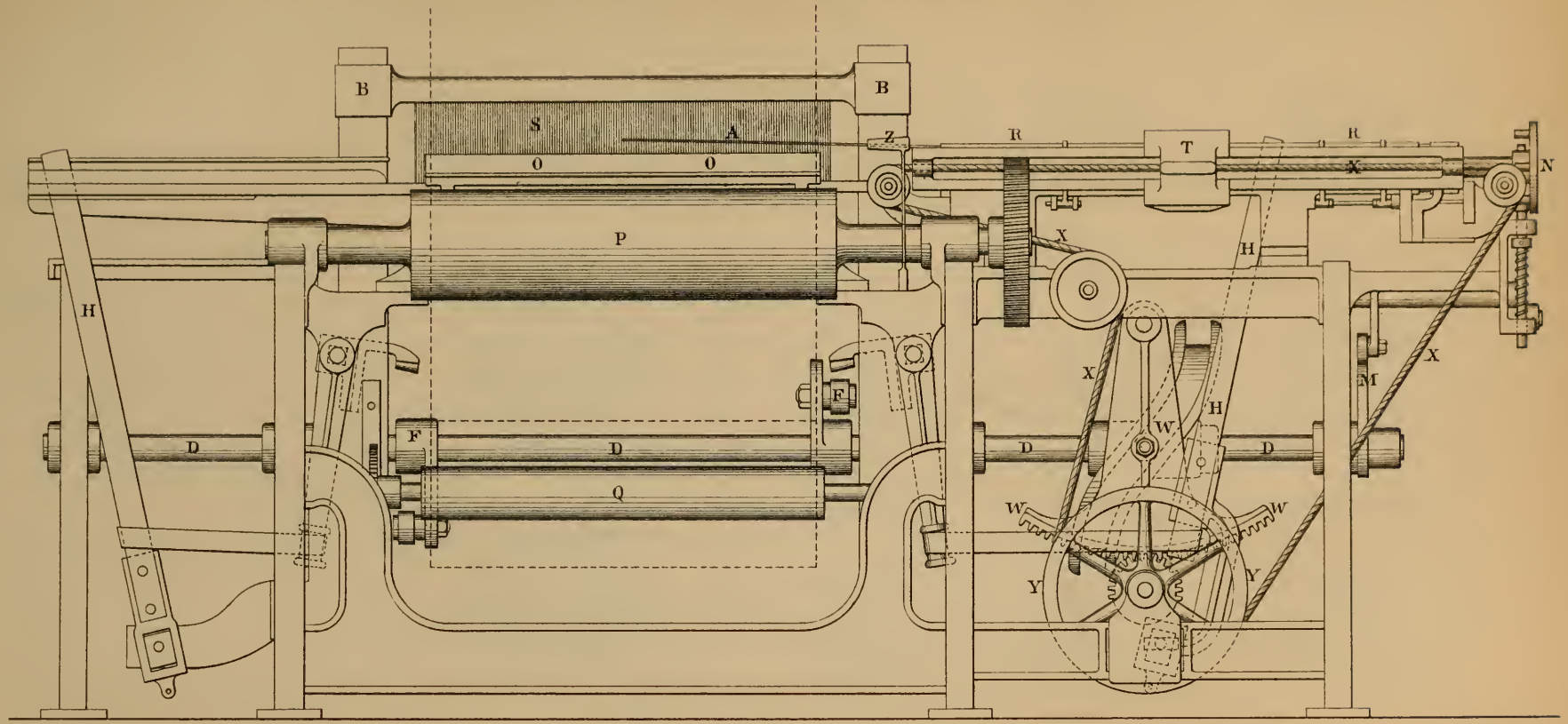


(Proceedings Inst. M.E. 1868.) *Scale* 1/15 th

BRUSSELS CARPET LOOM.

Plate 100.

Fig. 3. *Front Elevation of Loom.*



(Proceedings Inst. M.E. 1868.) *Scale* 1/15 th

10 5 0 10 20 30 40 50 Inches.

BRUSSELS CARPET LOOM.

Fig. 4. *Plan of Creel Frame.*

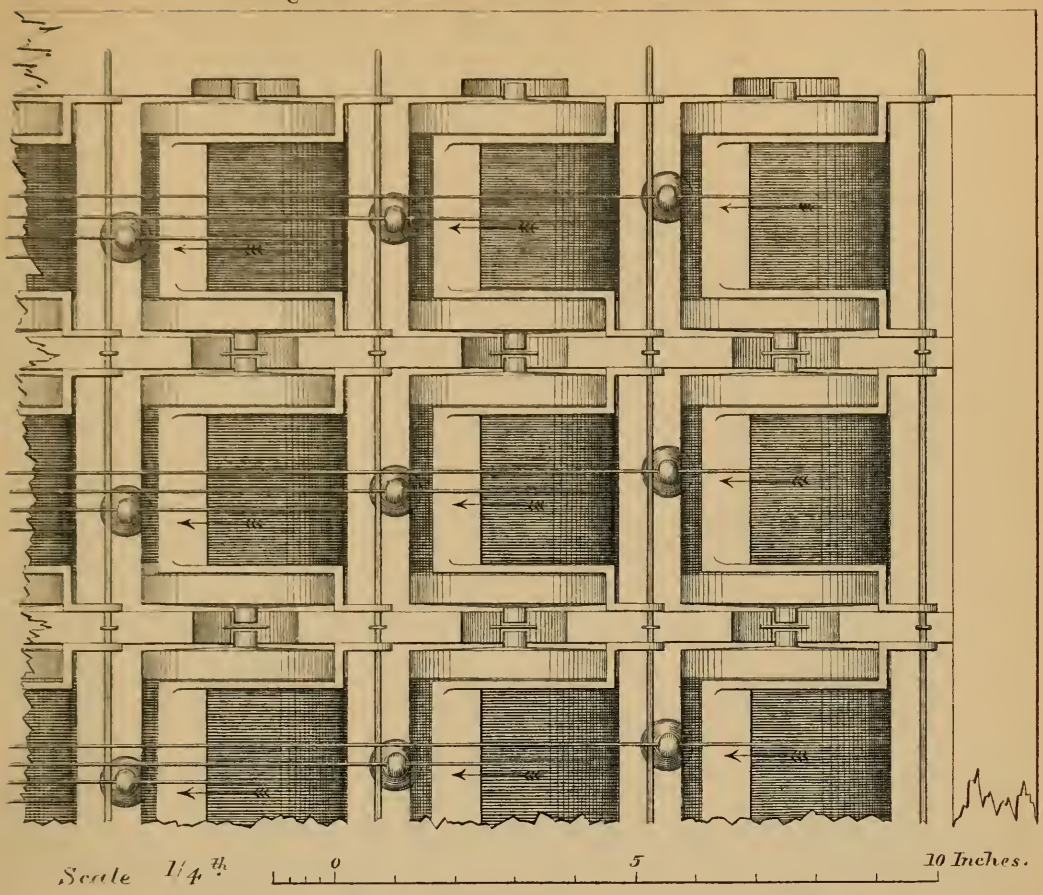
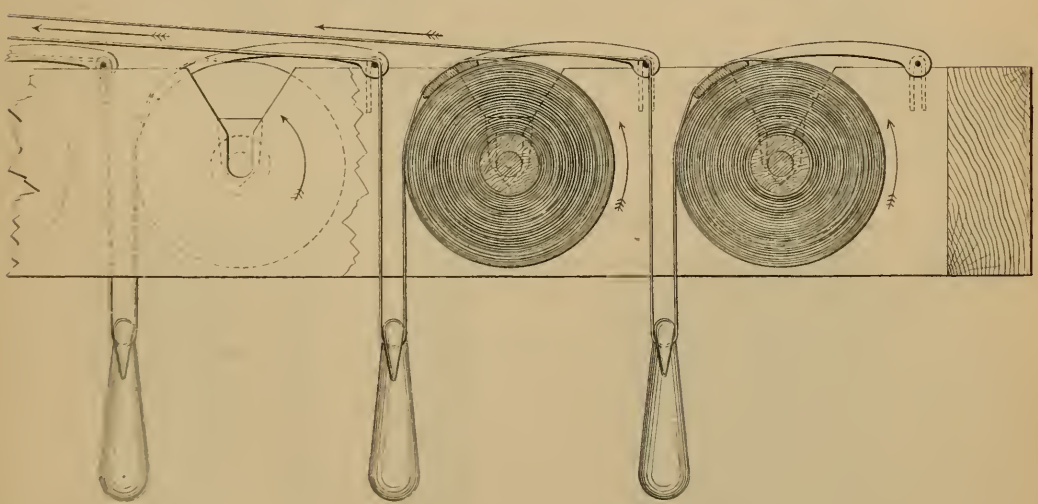


Fig. 5. *Side Elevation of Creel Frame.*



Wire for Brussels Carpet Loom.

Fig. 6. *Side View.*

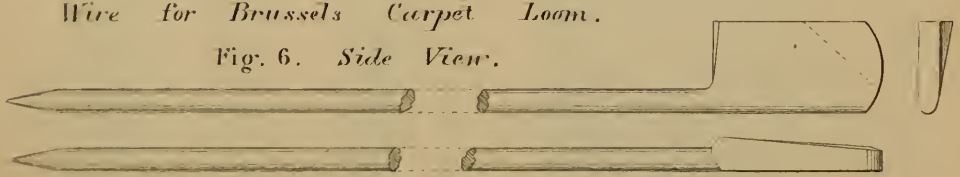


Fig. 7. *Edge View.* *Full size.*

(Proceedings Inst. M. E. 1868.)

BRUSSELS CARPET LOOM.

Fig. 8. *Elevation of Roller Wire-Motion.*

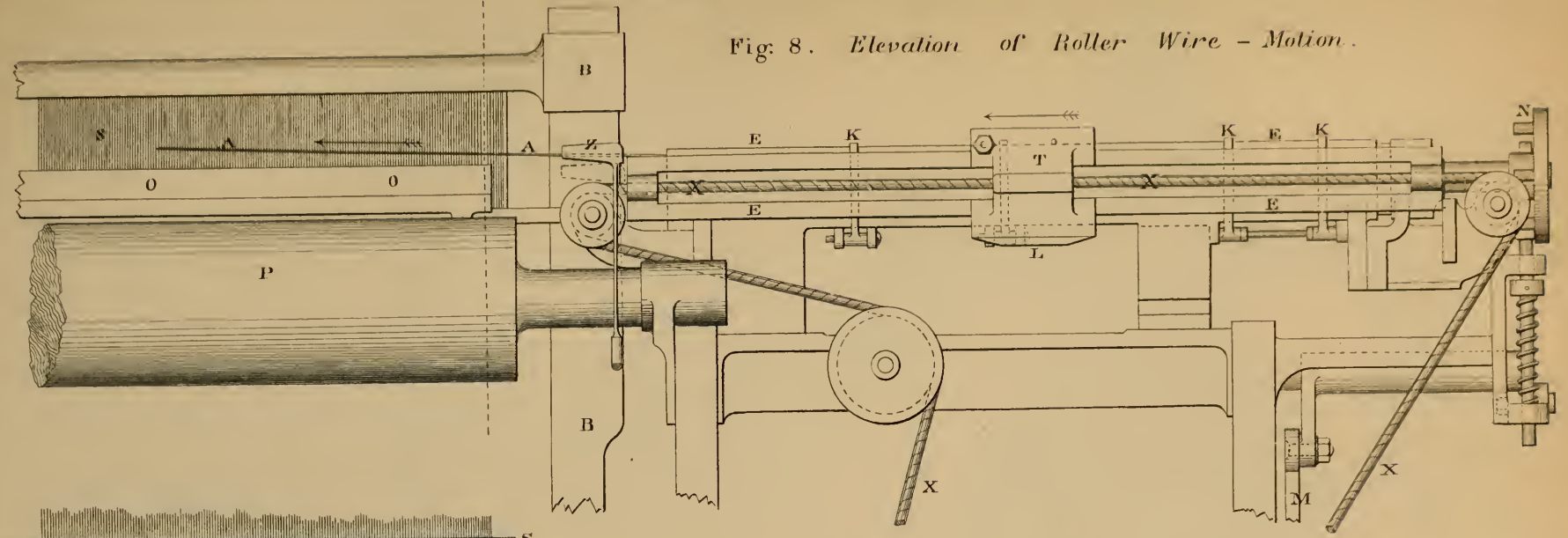
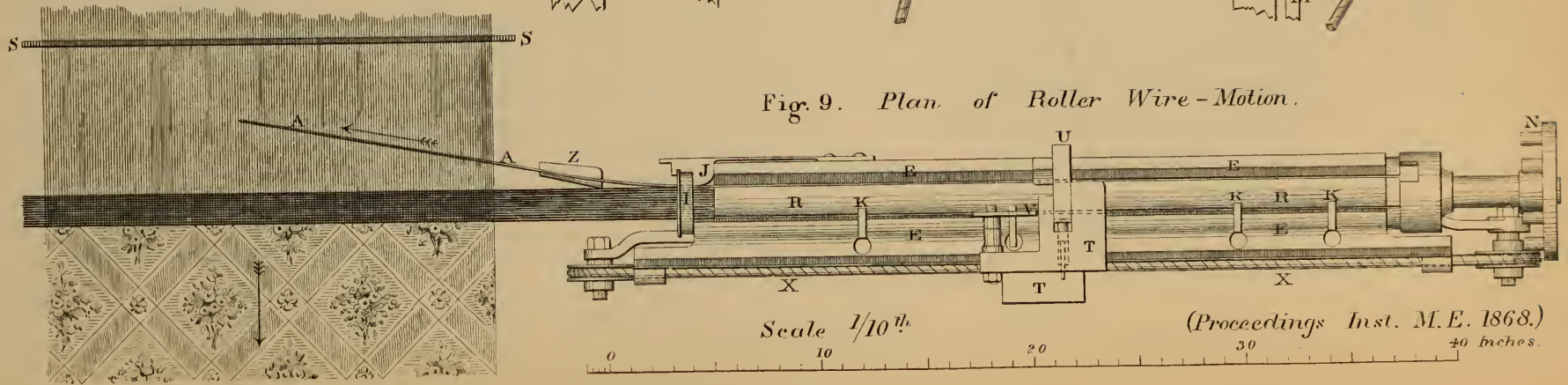


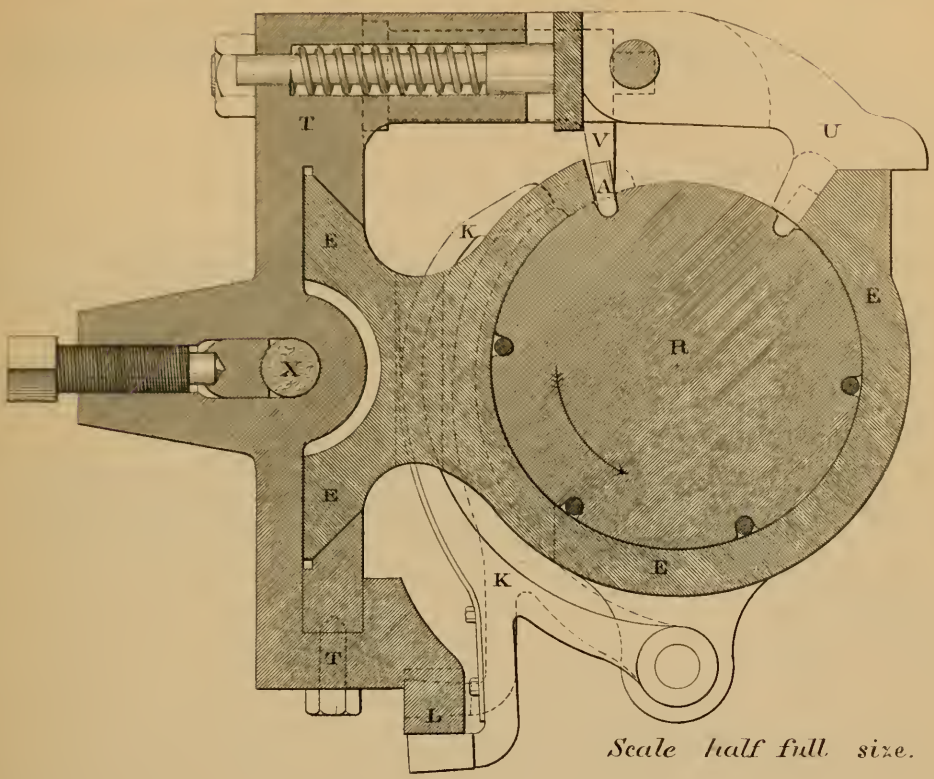
Fig. 9. *Plan of Roller Wire-Motion.*



Scale 1/10th.

(Proceedings Inst. M.E. 1868.)

Fig. 10. *Transverse Section of Roller Wire-Motion. Scale 1/2.*



Scale half full size.

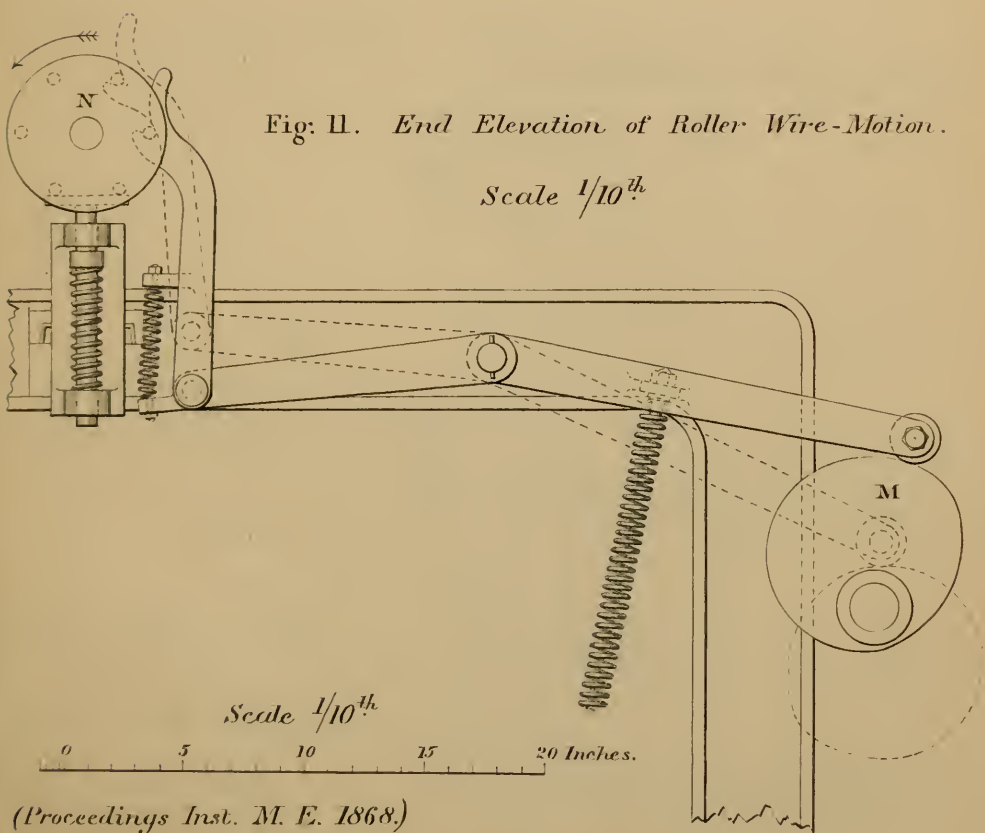


Fig. 11. *End Elevation of Roller Wire-Motion.*

Scale 1/10th

(Proceedings Inst. M. E. 1868.)

Diagrams of Longitudinal Sections of Warp-pile Carpets.

Fig. 12. *Tapestry Carpet.*

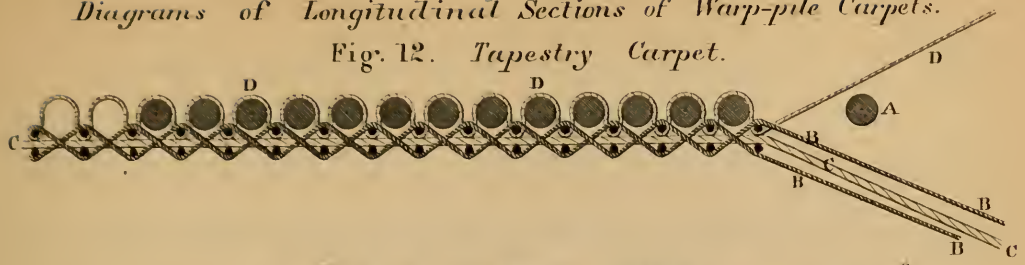


Fig. 13. *Brussels Carpet.*

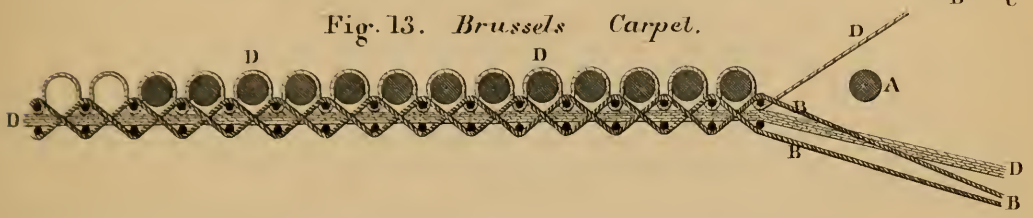


Fig. 14. *Velvet or Cut-pile Carpet.*

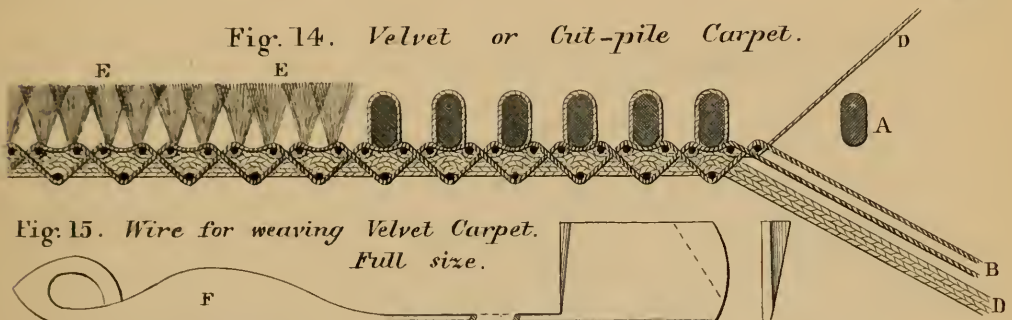
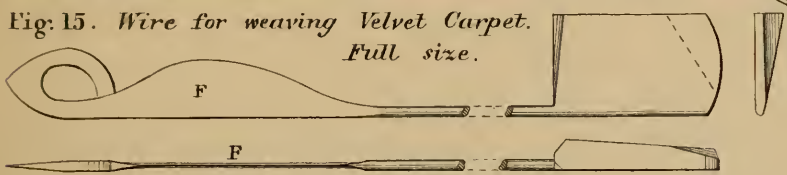


Fig. 15. *Wire for weaving Velvet Carpet. Full size.*



Diagrams of Sheds formed in weaving Brussels Carpet. Scale 1/10th.

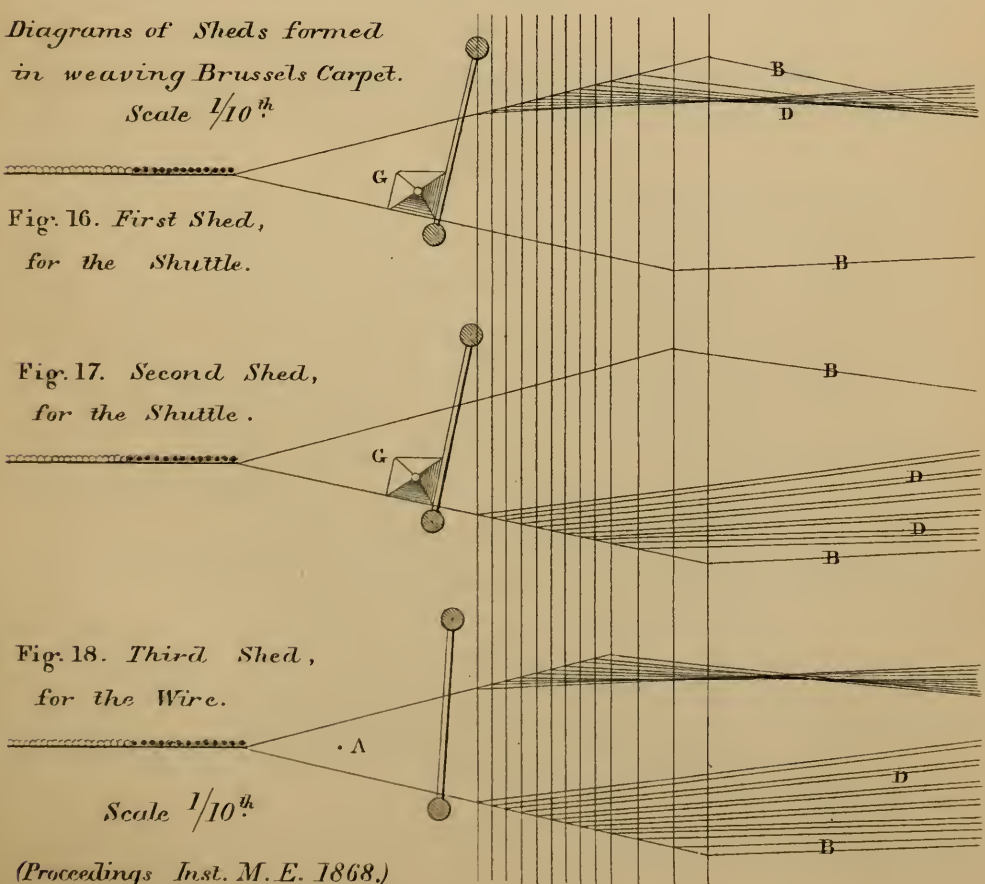


Fig. 16. *First Shed, for the Shuttle.*

Fig. 17. *Second Shed, for the Shuttle.*

Fig. 18. *Third Shed, for the Wire.*

Scale 1/10th.

(Proceedings Inst. M. E. 1868.)

ON THE CORLISS EXPANSION VALVE-GEAR FOR STATIONARY ENGINES.

By Mr. WILLIAM INGLIS, of Manchester.

At the present period of steam engineering it may be said that in the complete practical application of the expansive action of steam rests the only prospect of further economy, excepting that arising from improvements in the generation of the steam; and this practical application of the expansive action of steam has been, and still continues to be, a subject of great difficulty, from the fact that among the many plans of expansion gear very few answer even approximately the intended purpose. The Corliss Expansion Gear for Stationary Engines, forming the subject of the present paper, has until the last few years been little known in this country. The rapid increase of its application however, which has now taken place in this country, has warranted its being brought under the notice of the Institution.

The Corliss engine introduced by Mr. Corliss in the United States about twenty years ago, which in all except the cylinder with its valves and valve-gear is substantially the same as any ordinary steam engine, embodies in the arrangement of the cylinder and valve-gear several principles that had previously been used separately.

First, independent ports are used for admitting and for exhausting the steam at each end of the cylinder, with four separate slide-valves worked from a single eccentric.

Second, the steam is cut off from the cylinder by the main steam valves, without the employment of any supplementary valves for the purpose.

Third, the steam valves are opened against the resistance of springs, and a liberating gear is employed by which the valves are disconnected and left free to be closed by the springs.

Fourth, after the valves are closed, the springs are brought to rest without shock by the application of the contrivance known as the "dash-pot." This consists of a small cylinder with closed bottom, in which a piston is fitted to work easily; and by a suitable arrangement of openings the air is admitted freely to the cylinder while the piston is moving, except when it approaches the bottom, at which time a certain amount of air is imprisoned, forming a cushion to prevent any shock when the piston actually reaches the bottom.

Fifth, the speed of the engine is regulated by the governor acting on the steam valves to cut off the steam earlier, instead of acting on a throttle-valve to reduce the pressure of the steam.

It is the embodiment of these several principles, and the arrangement and construction of the details in the mechanism employed, rather than the application of any new or untried principle, which constitute the special features of the Corliss valve-gear.

Cylinders with four separate passages and independent steam and exhaust slide-valves were used by Seaward previously, the valves employed being flat slides, but not worked in connection with any liberating gear; and a number of marine engines were made on this plan. In the earlier Corliss engines Seaward's cylinders and slides were used; but the valve now employed is a cylindrical slide working in the arc of a circle on its seat, and receiving a rocking motion from a central valve-spindle. Although separate valves and passages were employed previously for steam and for exhaust at each end of the cylinder, the motion imparted to the steam valves was invariable, and any expansion of the steam was effected by the lap of the valve. The speed of the engine also had to be controlled by throttling or shutting off the steam with a supplementary valve; and in this respect the first step in advance is made in the Corliss gear by the addition of the principle of liberating the steam valves. With the employment of liberating gear it became necessary that an independent force should be available for closing the valves when they were detached, and for this purpose weights were first used; but springs have since been substituted for the weights, because they are quicker in action, effecting a sharper cut-off, and are better adapted for quick working.

Liberating gear for the steam valves was indeed used by Watt, so that the principle may be considered almost as old as the steam engine itself; but in Watt's time it was more frequently for opening than for closing the valves that the weights used in that method of working were employed, and as might be expected the mechanism was not very perfect in its details. At that time the drop or poppet-valve was used for the purpose.

To Mr. Sickles of New York is due the credit of perfecting the liberating gear as applied to the poppet or the double-beat valves, in the cut-off gear which bears his name. In this valve-gear, which was introduced in 1841 in America, the dash-pot is applied direct to the valve itself, to arrest the progress of the valve and prevent it from striking on its seat. It should be observed that there is an essential and important difference between the use of drop-valves and slide-valves, in connection with liberating valve-gear; for in the one case the dash-pot is applied to arrest the valve itself and prevent it from striking on its seat, but in the other it is only required to prevent the concussion of the weight or spring that is used to close the valve. If the drop-valve, in order to prevent concussion, is made to fall slowly just as it approaches its seat, it is evident that there must be a certain amount of wire-drawing of the steam; whereas with the slide-valve the motion of the spring or weight which closes it is not arrested by the dash-pot till after the valve is closed and the steam completely cut off: hence while the cut-off with the slide-valve must be perfect, with the drop-valve it must at best be to a certain extent imperfect.

Regulating the speed of steam engines by connecting the governor to vary the degree of expansion, instead of throttling the steam, was advocated, if not practised, by Watt, and many different arrangements have been invented and applied for effecting this object. In the Corliss expansion gear the governor is connected to the clips used to liberate the steam valves, and according as the pressure of steam in the boiler or the load on the engine varies, the supply of steam to the cylinder is cut off at an earlier or later period of each stroke; so that the speed of the engine is kept uniform, without the addition of any throttle-valve in the steam pipe. While the steam valves are thus

controlled by the governor, and caused to close at an earlier or later period of the stroke to suit the varying conditions of the steam pressure or load on the engine, the exhaust valves have an invariable motion, and are opened and closed at the same point of the stroke, whatever may be the degree of expansion.

The disconnecting valve-gear for working the steam valves, as originally introduced by Watt and applied for the purpose of opening or closing poppet-valves, is shown in Fig. 1, Plate 88. It was usual in this gear to communicate motion to the valves by a rod A called a plug-tree, attached to some moving part of the engine, generally to the beam; on this rod were fitted tappets B B, to open or close the valves when moving in one direction, and when moving in the opposite direction to trip or liberate the catches and allow the weights to act for either closing or opening the valves, as might be arranged. The drawing shows the plug-tree A with its tappets B B, the valve C, the catch D, and the curved lever E for tripping the catch, the weight F for closing the valve, and the dash-pot G for bringing the weight gradually to rest when dropped. All the details are rude and clumsy, but it can be seen that there is in this arrangement the germ, so to speak, of the Corliss expansion gear.

In Fig. 2, Plate 88, is shown the arrangement of gear employed in the earlier Corliss engines in America for actuating the steam valves; and the contrivance used for tripping or liberating the catch, in connection with a governor, to produce the sudden closing of the valves. In this arrangement a weight H was used, attached to a lever on the valve-spindle I, to supply the external force for closing the valve when the catch K was liberated, the weight falling in a dash-pot similar to that in Watt's gear. This plan was improved several years ago by Mr. Corliss, who then introduced an arrangement in which the catches push the valves open instead of pulling them, and the valves are closed by long blade-springs fitted to vibrating levers. The tripping of the catch is effected by curving up the back end at K, and this end when moving forwards comes into contact with a plate L, which is acted on by a rod M connected with the governor; the rod M carries an incline, which raises or lowers the plate L

according to the changes in position of the governor balls, so that when the plate is lowered by the governor balls flying out in consequence of excess of speed, the catch K is tripped sooner, and reduces the supply of steam to the engine by cutting off the steam earlier. A few engines fitted with this arrangement of gear were made in this country some years ago, but the plan appears to have since fallen into disuse.

The present improved construction of the Corliss engine is shown in Fig. 3, Plate 89, which is a side elevation of the cylinder and valve-gear of a small horizontal engine made by Messrs. Hick Hargreaves and Co. of Bolton for the Royal Arsenal at Woolwich, from designs by the writer. This engine, which has 12 inch cylinder and 2 foot stroke, works at 100 revolutions per minute. The cylinder is shown in transverse section in Fig. 4, Plate 90, and in longitudinal section in Fig. 5. The steam valves AA are placed on the top of the cylinder, and the exhaust valves BB at the bottom, separate pipes leading from them at each end of the cylinder. The steam valves are closed by a spring dash-pot CC, which pulls upon each valve-rod as it is drawn out; and the liberating gear consists of a pair of side spring-clips DD, which are released by the rocking of a double toe-lever EE, and then allow the steam valve to be closed by the action of the spring: the spring-clips and toe-lever, and the valve-gear generally, are similar to those afterwards described in the Saltaire engines. The valves are cylindrical on the face, being similar in action to ordinary slide-valves, but working upon a cylindrical instead of a flat face; the valve face is a longitudinal segment of a cylinder, having recesses on its inner side, into which drop the projecting arms of the valve spindle, so that the valve is moved by the partial rotation of the spindle in opposite directions alternately. The pressure of the steam on the valves tends to press them up to the face, only when the ports are closed; so that when the ports are opened, the valves move with practically no friction from the steam pressure, and thus the pull required to close the steam valves is small, and is practically independent of the pressure of the steam.

The cylinder is steam-jacketted both on the body and on the ends; and an improvement in the construction of these cylinders has recently been introduced by the writer, considerable trouble having been experienced in getting the jacketted cylinders sufficiently hard when cast in one piece, on account of the risk from cracking if cast with hard metal, and also in consequence of the annealing process that takes place during the cooling of the castings. The improvement consists in making the cylinder and valve-chest in four distinct pieces, with flanged face-joints F F to connect all together, as shown in Fig. 5. The cylinder and the steam-jacket are two concentric castings, fitting one inside the other, with a flange F F upon the jacket only; and a separate casting at each end forms the valve-chests above and below the cylinder, with a ring connecting the two valve-chests; the end of the cylinder is fitted into this ring, and the cylinder cover is fixed upon it, all the fitting surfaces being turned and bored. The separate castings are thus rendered quite simple, and can be made of any degree of hardness without risk; while the flanged face-joints provide security against leakage, much better than if the inner cylinder were simply let in, with slip joints parallel to its bore. A saving of time in making can also be effected, as the work on the separate pieces can be proceeded with in several machines at the same time.

Figs. 6 and 7, Plates 91 and 92, show a front and side elevation of one of the new cylinders with the improved Corliss expansion gear that have recently been erected at Saltaire by Messrs. Hick Hargreaves and Co. from designs by the writer. The engines are beam engines coupled together, with 50 inch cylinders and 7 foot stroke, working at 30 revolutions per minute. There are two pairs of engines to be replaced, four cylinders in all, and the new cylinders have been put in place and now completed for one pair, and are the same size; the previous cylinders had double-beat valves actuated by a cam motion. Figs. 8, 9, and 10, Plates 93 and 94, are vertical and horizontal sections of one of the cylinders, showing the valves. The cylinders and cylinder covers are steam-jacketted; and the valve chambers are cast with the cylinders. The steam

valves C C are in front and the exhaust valves D D at the back of the cylinder, and the valve-gear is placed on the sides of the cylinders between each pair of engines. The steam and exhaust passages E E are cast separate from the cylinder, and provided with expansion joints F F, shown in section in Fig. 8. The valves are cylindrical on the face, similar in construction to those of the Woolwich engine previously described. All the four valves are opened by the eccentric rod T, Fig. 7, acting on an oscillating disc U, to which the four valves are connected by rods; the exhaust valves D D are also closed by the same means, but the steam valves C C are released, and are closed by an air-spring P. The stop-valve G in the steam passage is similar in make to the steam valves, and is opened by a worm and wormwheel to regulate the supply of steam; but it can be closed suddenly on any emergency by means of the lever handle H, which is keyed upon the valve spindle and is connected to the wormwheel by a detent that can be instantly disengaged, the wormwheel being loose upon the valve spindle. A small auxiliary conical stop-valve I opened by a screw handle is employed for turning on the steam gradually at starting, to relieve the pressure on the main stop-valve G.

The construction of the liberating valve-rod introduced by Mr. Spencer and the writer, for the disengaging gear to release the steam valves, is shown in Figs. 11, 12, and 13, Plate 95. The valve-rod is divided into two portions, one sliding steadily within the other at the cylindrical part A A; and the two are held together by the pair of spring-clips B B fixed on one portion, which rest on corresponding shoulders C C on the other portion of the valve-rod. The clips are released by the double toe-lever D, which rocks upon a transverse centre pin, and is shown in its two extreme positions in Figs. 11 and 12; the outer end K of the arm of the toe-lever being held by the rod L shown in the general drawing Fig. 7, the toe-lever D is made to rock in each stroke of the valve-rod, and the particular point of the stroke at which the toe-lever reaches its extreme position and disengages the spring-clips B B is determined by the position of the end K of the toe-lever arm, which is not stationary, but is acted on direct by the governor through the rod L. By this means all changes

in position of the governor balls produce corresponding changes at the same time in the position of the fulcrum upon which the toe-lever acts, causing the release of the spring-clips to be earlier or later in the stroke according as the speed of the governor is greater or less than the correct rate, and thus regulating the engine by cutting off the steam earlier or later accordingly. The disengaging rods L L from the two steam valves are coupled together by a pair of toothed segments M M, shown in Fig. 7 and also in the enlarged drawing Fig. 14, Plate 96; and the rod N, Fig. 7, connects these with the governor. The spring-clips B B fall upon leather faces O O, to prevent any blow in closing; and the engaging edges of the clips and the shoulders are hardened steel faces let in and readily renewable.

The air-spring dash-pot P for this gear, Fig. 7, is shown enlarged in Fig. 14, Plate 96, one half in section. It consists of two cylinders, one within the other; the large cylinder has a loose-fitting piston R R, and the small cylinder a trunk piston S S fitted with metallic packing; the underside of this trunk piston is in connection with the condenser. The pressure of the atmosphere is therefore constantly pressing the small piston in, and this forms the spring for instantly closing the steam valve when liberated from the clip-rod; the large piston R is coupled to the small one S, and acts as a dash-pot to prevent concussion in closing the steam valve, as the air below the loose-fitting large piston R has to be driven out at the moment of closing the valve.

The double-clip gear, as far as experience goes, works with satisfaction, and is reliable and effective up to the speed of 100 to 120 revolutions per minute; and it could be worked at speeds considerably greater. More than sixty land engines, most of them of large size, are now at work in this country fitted with this gear, and many of these have been at work for several years, giving great satisfaction both in economy of fuel and regularity of speed; a considerable number of the engines have also been made and sent abroad. These engines have also been applied to steamers, and their use is rapidly extending for marine purposes. The arrangement of the valves and gear makes them easy of access either for inspection

or repair; and from the number of engines satisfactorily at work it has been proved that with good workmanship the valves and gear can be kept in order at a very trifling expense.

The consumption of fuel with these engines is about $2\frac{1}{2}$ lbs. of coal per indicated horse power per hour, which includes all the coal used for raising steam or banking fires. Indicator figures taken from the Saltaire engines are given in Figs. 15 and 16, Plate 97.

In conclusion the writer desires to add, with reference to the alterations of the Saltaire engines, that he was aided in the preparation of the designs by many valuable suggestions from Mr. George Salt, through whose kindness the members of the Institution will have an opportunity of seeing the engines at work on the present occasion.

Mr. Inglis showed a specimen of the spring-clip liberating gear as used in the Corliss engines at Saltaire.

Mr. W. M. Neilson enquired in reference to the valves of the Corliss engine, whether there was any provision for keeping them up to the face of the ports, as they worked up a curved surface; and whether any difficulty was experienced in making up the wear of the valve faces.

Mr. Inglis replied that the valve face was simply a portion of a cylinder moving round upon a cylindrical surface a short distance backwards and forwards, and was just similar in action to an ordinary flat slide-valve moving upon a flat surface; and it was kept up to the face of the port in the same way, simply by the pressure of the steam. The valves were of cast iron, and the wear was as uniform over the face as in an ordinary flat slide-valve; and they were driven by projecting arms on the central valve-spindle, which fitted easily into a recess on the back of the valve, leaving the valve resting free upon the port face.

Mr. F. J. Bramwell thought that the object to be aimed at in an engine was to combine economy in working with economy and simplicity in construction and repairs, but in reference to the engine described in the paper there appeared to him a serious complication of construction which would entail increased cost both in original construction and in repairs; and it did not seem to him, judging from the indicator diagrams shown, that the result arrived at was any greater economy of working than was obtained from well made engines of simple construction. The several contrivances that were combined in the engine had been tried before, as stated in the paper, such as the dash-pot, and the separate valves for steam and exhaust; and he remembered seeing the original Sickles cut-off valve-gear working in the river steamers of America. The special novelty in the present engine appeared to be the particular mode of effecting the liberation of the valve-gear in cutting off: this however was done by a most complicated piece of machinery, and he thought the question to be considered was whether any real advantage was gained to warrant this complication; especially when it was borne in mind that non-condensing engines were now seen at the agricultural shows which had only a single slide-valve with a cut-off slide at the back, and yet showed a consumption considerably below 3 lbs. of coal per effective horse power per hour, measured by the friction break. If such a high degree of economy could be practically obtained by so simple a construction, he thought the adoption of the complicated construction of the engine now described would be a retrograde step.

In the arrangement of the air-spring and dash-pot he thought there was a practical objection to the connection with the condenser of the engine, as any leakage of the trunk piston would allow air to pass into the condenser; while the great object now aimed at in condensing engines was to prevent entrance of air by every possible means, as for instance by the use of lantern brasses in the stuffing-boxes. He enquired what was the mode of starting the engine, before a vacuum was obtained in the condenser to supply the force required to close the valves.

Mr. E. A. Cowper said he quite agreed with the remarks of the last speaker; and considered an engine was wanted to do its work

steadily, and that as good indicator figures as those now shown could be obtained with a proper slide-valve and expansion gear, without the objectionable complication of triggers and springs, which though certainly very ingenious were not in his opinion suitable for an engine.

Mr. B. Walker thought it was not possible with any cut-off valve on the back of an ordinary slide-valve to produce so good an indicator figure as those now exhibited from the Corliss engine, which showed a decided economy in working. He thought there was a great deal of merit in the arrangement of the valve-gear, but feared the construction involved too much complication and too many loose parts to allow of its becoming generally applicable.

Mr. C. W. Siemens considered that the indicator figures exhibited were certainly very perfect, and that the arrangement of valve-gear shown was capable of producing an exceptionally perfect cut-off and exhaust. Such expansion figures could not be produced by the link motion, and it had to be remembered that with the back cut-off slide the figure obtained was not equally correct for all degrees of expansion; but by the valve-gear now shown a very correct figure was obtained for all degrees up to a very high point of expansion. He quite agreed however with the opinions that had been expressed about the complication of the gear, and thought that several of the mechanical details were of an objectionable kind; but it must be borne in mind that the arrangement was intended as a means for obtaining a very perfect result, and should be considered with reference to that object.

Mr. C. E. Amos thought that in an engine which had to be kept in regular work, simplicity of construction was one of the most important considerations; and however beautiful and perfect the arrangement might be, all complications should be avoided, as complication in the working parts was liable to involve extra wear and tear and expense in working, which might practically outweigh the other advantages. The addition to the original cost of an engine, caused by complication of construction, was also a serious consideration.

Mr. T. Hawksley observed that the main value of the special contrivance now shown appeared to consist in getting by the use of springs a higher velocity in the closing of the valves than

could otherwise be obtained; and then a higher speed of engine could be employed with a sufficiently quick action of the valves to give a good expansion. But though there might be some circumstances in which a high speed of engine was desirable, such as 400 feet per minute or more, he thought those cases would be comparatively few, and that the high speed would then be accompanied by an objectionable cost and loss from friction. The indicator figures shown from the engine were not sufficient he thought for forming an opinion as to the results, because an engine working with these disadvantages might exhibit quite as good a figure of expansion within the cylinder as an engine working without them; and consequently, though a good indicator figure was obtained from the engine, he feared the working effect would not be proportionate.

With regard to the determination of the effective horse power of an engine by means of a friction break, to which reference had been made, he thought the results obtained by that means were not to be relied upon for accuracy; for he had known instances of a large amount of error in the results obtained by employing a friction break as the measure of the power given off by a steam engine. A remarkable case of a similar nature was the measurement of the power obtained from turbines, the performance of which had been estimated by the use of a friction break to amount to 80 per cent. of the total power in the water expended, and in one case to even as much as 90 per cent.; but in fact the theoretical limit of the power that could be obtained from an absolutely perfect turbine was only 60 to 70 per cent., on account of the power unavoidably left in the discharged water flowing from the machine. He thought therefore that the very high results which had been stated to be obtained from agricultural engines by measurement with the friction break would be found to require a considerable correction, on account of error involved in the use of the friction break for this purpose.

Mr. C. E. Amos said he had had long experience in the use of friction breaks for measuring power transmitted, and was satisfied that when properly constructed their results were fully to be relied upon. One of the most striking illustrations of their accuracy was afforded in the laying of the Atlantic telegraph cable, where a

dynamometer was used, with a friction break on Appold's improved plan, for measuring continuously the strain upon the cable whilst paying it out from the ship; and the action of this dynamometer was so delicate and sensitive that the slightest increase in the strain upon the cable at any moment was instantly indicated. The breaks were loaded to a definite point, at which the cable should slip; and it was always found to slip directly the strain reached that point. On another occasion in the Bay of Biscay some experiments were made with a similar cable dynamometer, and the depth of water calculated from the indicated strain upon the submerged cable was found to agree closely with the actual depth measured by sounding.

Mr. C. W. Siemens fully agreed in the correctness of the indications afforded by the friction break, and considered there could be no better illustration of the correctness of the principle than in the laying of submarine cables, where the safe management of the operation was entirely dependent upon the use of the break dynamometer. Also in the case of measuring the power given off by a steam engine, he considered the result obtained by calculation from the load sustained by a friction break driven by a shaft or belt from the engine must give the correct measure of the power transmitted by the shaft or belt, as all required deductions were thereby made for loss of power by friction and imperfections in the engine. In regard to the other application of the friction break that had been referred to, for measuring the power obtained by a turbine from moving water, the measure given by the friction break could not exceed the power actually given out; and in the case therefore that had been mentioned, where the measurement of the power obtained by turbines had appeared to exceed the theoretical limit possible, he thought the gross power residing in the water must have been under-estimated.

Mr. T. Hawksley considered that the friction breaks used for measuring the power transmitted from engines were defective in the mode in which the power to be measured was taken off by the break. They were generally constructed on the plan that might be termed "dithering" breaks, in which the action was not steady and continuous, but the break was constantly jumping up and down,

alternately biting and slipping, and was really doing no work at the moments of jumping off the wheel, although it was registering the full load throughout, and consequently indicating too high a result.

Mr. G. D. Hughes believed that in several cases indicator figures which he had taken had as good an expansion curve as those now shown, with the steam cut off as early, and as good a vacuum line; and in these cases the engines had an ordinary slide-valve, with a cut-off slide on the back which was adjusted by the governor, controlling the speed of the engine without any throttle-valve. He thought it would be going back to adopt so complicated a construction for effecting the object as in the engine now shown; and considered the complexity would be found to involve a sacrifice in first cost and a great liability to get out of repair.

Mr. J. C. Amos considered it was quite practicable to produce as good a diagram as those now exhibited, with a simple valve and a back cut-off slide; and the only advantage in the construction of engine now shown appeared to be the facility afforded for regulating the degree of expansion by the action of the governor, which notwithstanding the very numerous attempts that had been made could not be said to have been thoroughly accomplished yet with the ordinary slide-valve. The completeness with which this was effected in the plan now shown appeared to him the only good reason for departing from the simplicity of the ordinary double slide.

Mr. R. Douglas remarked that he had had considerable experience in the manufacture and working of the Corliss engines, and could bear testimony to the fact of there not being that tendency to derangement of the working parts which seemed to be supposed; on the contrary the whole of the valve-gear was found to be very durable and satisfactory in working. He knew some of these engines had been in regular work for the last four years, running night and day, and their valves were still perfectly tight, and the steel catches of the liberating gear were now as square and sharp at their engaging edges as when first made, though they had been working the whole of the time; there was in fact only a very slight source of wear upon them, because at the moment of disengaging there was only the pull of the spring upon the catches that were released, and the valve

was then open with no pressure upon it, and requiring consequently very little power to move it. He had fixed Corliss engines in many cases in the place of other engines, and had effected by the change a saving of one third in the consumption of fuel in all instances, and in some cases even more. It was very difficult however to make correct comparisons of engines in this respect, on account of the great variations in the conditions; but in another respect, namely the undeviating uniformity of speed, there was no question as to the advantage gained with the Corliss engine. In one instance of an ordinary engine driving a flax mill, where two thirds of the mill was driven from one cog-wheel, this wheel had got stripped on one occasion previously to the change of engine, and the result of the acceleration in speed of the engine in consequence of two thirds of the work being suddenly thrown off was that the threads in all the remaining spinning frames were broken; but after the Corliss engines were substituted, although a similar accident happened from the stripping of the teeth of the same cog-wheel, not a single thread was broken in the spinning frames, as the supply of steam to the engines was instantly diminished to correspond with the diminished load. He did not know how such a regulation of the speed could be accomplished by any arrangement of a cut-off slide working on the back of another; but in the Corliss engine the steam-valves were completely thrown out of gear at every stroke, so that when the engine was making 30 revolutions per minute the steam supply was regulated 60 times in a minute, which gave a great nicety in regulating the speed of the engine.

Mr. Inglis said that the valve-gear in the Corliss engines, although appearing complicated, did not really involve any practical objections in working, as the working parts were very durable and were subjected to very little wear. There had never been any trouble with any of these engines, although more than sixty of them were already in use in this country; and they had given such entire satisfaction in their working that there were now nearly twenty more of them in progress. A decided economy in consumption of fuel was found to be effected by these engines, where a comparison with other engines working under the same circumstances could be made. At

Woolwich Arsenal, where four of the Corliss engines were in use, a careful trial had been made during three months' working, and the result was found to be considerably in their favour in cost of working; their total average consumption during that time was $2\frac{1}{2}$ lbs. of coal per indicated horse power per hour, with a steam pressure of 45 lbs. per inch. The general working of other engines would be found he thought to average nearly 5 lbs. per indicated horse power per hour, and he believed more than half of the engines included in the Manchester Boiler Association were fully up to that amount or above it. The pair of Corliss engines at Saltaire, which had now been working about two months, would afford a good opportunity for comparison of results with the original pair of engines continuing to work alongside of them under exactly similar circumstances, the only difference being that the cylinders were not steam-jacketted in the original engines.

In reference to the enquiry about the arrangement for starting the Corliss engine, before a vacuum was obtained in the condenser for supplying the spring to close the steam valves in cutting off, the valve-gear was arranged not to be liberated at all when the governor was down in its lowest position; so that at starting the engine the valve continued connected to the gear throughout the stroke, and consequently did not require the air-spring for closing it; but by the time the speed was increased sufficiently for bringing the governor into action and liberating the valve at each stroke, a vacuum had been obtained in the condenser so as to effect the closing movement by the air-spring.

Mr. H. Woods thought that a consumption of 5 lbs. per horse power per hour was too high a figure to be taken for general comparison, and that such a consumption could apply only to defective engines.

Mr. T. Hawksley did not understand how any great difference in consumption could arise in really good engines, under the same circumstances of good condition, if the degree of cut-off were the same in both the engines compared; for when the steam was once shut into the cylinder, its expansion would be the same in both cases, and any difference in the indicator figures would be chiefly due

to condensation in the cylinder from the want of a steam jacket, which however could not amount he thought to more than an additional consumption of $\frac{1}{2}$ lb. of coal per horse power per hour. Any greater difference he thought must really be due to the two engines compared not being in equally good working condition; but if the two engines had their cylinders equally warmed by steam jackets, the same expansion curve in the indicator figure would be obtained from both, if the steam was cut off at the same point and at the same pressure in both, although one might be a good engine and the other a bad one.

Mr. Inglis observed that the expansion curve was affected materially by the amount of clearance at the ends of the cylinder, which in some engines amounted to a considerable proportion of the contents of the cylinder; but in the Corliss engines the clearance was reduced to an unusually small proportion by the arrangement of the valves, and in the Saltaire engines it amounted to only $2\frac{1}{2}$ per cent. of the capacity of the stroke, including both the clearance and the contents of the ports, whereas in other makes of engines it was usually considerably more. The area of the exhaust passages in the Saltaire engines was 1-10th of the cylinder, and the steam passages 1-16th. The sharpness of cut-off in the Corliss valve-gear prevented the loss that was generally shown in an indicator diagram from the rounding off of the top of the figure; and the uniformity in the action of the valve-gear prevented the inequality that was generally found in other cases in the supply of steam at the two ends of the cylinder. There was also a great advantage in working entirely from the governor, so as to regulate the speed of the engine by the degree of expansion, thereby getting always the full steam pressure in the cylinder up to the point of cut-off, instead of wire-drawing the steam pressure by contracting the opening of a throttle-valve in the steam pipe.

The Chairman remarked that the subject was one of great practical interest and importance, and required close investigation, both as to the real economy in working of the new engines and as to the actual wear and tear attending the complication in their construction. There would be an unusually good opportunity for comparison

between the new engines at Saltaire and the original engines, provided one pair were retained for a few months to work against the other pair that was altered; it would then be seen what advantage, if any, was derived from the change. The original engines, which had been made at his own works, had been at work about twelve years and had given great satisfaction. They were plain single-cylinder beam engines, with double-beat valves worked by a cam motion adjustable to different degrees of expansion. Improvement in the construction of steam engines was certainly a subject of great practical importance, and it was desirable that any improvement such as the one before the meeting should be thoroughly investigated; and the members would have a good opportunity, through the kindness of Mr. Salt, of examining both the new and the old engines at work at Saltaire that afternoon.

He moved a vote of thanks to Mr. Inglis for his paper, which was passed.

The following paper was then read:—

ON THE MACHINERY FOR WEAVING BRUSSELS CARPET BY POWER.

By Mr. WILLIAM WEILD, of Manchester.

In Carpets and other pile fabrics, there are interwoven, between the threads of the ordinary plain fabric forming the body or back of the carpet, other threads, generally of a different material, which are interwoven in such a manner as to form a terry, looped, or pile surface. In the actual weaving there is therefore little difference between pile fabrics and plain or jacquard fabrics, the additional mechanism required for the pile fabrics being only such as will form the pile threads into loops on the surface of the fabric during the process of weaving. The substitution of self-acting machinery for weaving carpets and other pile fabrics, in place of the previous hand labour, has occupied the particular attention of machinists for more than twenty-five years, and many arrangements have been invented for effecting this object; but it was only between 1851 and 1856 that machinery for the purpose was so far perfected as to be commercially successful.

There are two classes of pile fabrics: those in which the pile is formed by the "weft" (the threads passing crossways of the piece); and those in which it is formed by the "warp" (the threads passing lengthways of the piece): but it is only the latter class that is referred to in the present paper. Various methods of weaving warp-pile fabrics have been proposed, some of which are in use at the present time. Hat-plush or velvet is manufactured by weaving two pieces at the same time, face to face, the pile warp being bound alternately in each piece; and the two pieces are afterwards separated by cutting the connecting pile, so that each piece contains half of the pile warp. Terry or looped fabrics have been manufactured in various ways; but the method most usually adopted for forming the loops of the pile is by means of wires placed in the

"shed," that is the opening between the threads through which the wire passes across the fabric. This plan is practised in weaving by hand, and is generally admitted to be the best method yet known for making a good and regular terry or looped pile-fabric. The wire is introduced into the shed between the pile threads and the body warp, so that when the pile threads are afterwards bound down again in the body of the fabric they form loops over the wire, which is subsequently withdrawn from the fabric. The object aimed at in most of the inventions for weaving pile fabrics by power with the use of wires has been to combine mechanism for inserting and withdrawing the wires with the mechanism of the ordinary power loom employed for weaving either plain or jacquard patterns.

Three descriptions of warp-pile fabrics are manufactured, which are known as Tapestry carpet, Brussels carpet, and Velvet or Cut-pile carpet, the construction of which is illustrated by the diagrams Figs. 12 to 14, Plate 104.

In Fig. 12 is shown a longitudinal section of a Tapestry carpet, with a shed formed for the new wire A to be inserted. The body of the fabric is formed by the two sets of warp threads B B, which are generally linen threads; these are interwoven with the weft, the threads of the weft being seen in section in the diagram; and in addition there is generally a warp of thick soft threads C, for the purpose of giving sufficient thickness and substance to the fabric. In this construction of carpet these thick threads C remain always in the middle of the fabric, and the weft passes above and below them across the carpet, as shown in the diagram. The pile threads D never descend below the thick threads C, and consequently never appear at the back of the carpet; and in the operation of weaving the whole number of the pile threads are raised and lowered simultaneously; when raised they form the shed for the new wire A to be inserted beneath them, as shown in Fig. 12. Where there are designs in colour upon a tapestry carpet, they are produced by each separate pile thread being made parti-coloured and arranged in such a manner that when woven over the wires a pattern is produced by plain weaving.

In Fig. 13, Plate 104, is shown a longitudinal section of a Brussels carpet, with a shed open for the new wire A to be inserted. Here the body warp B is the same as for tapestry carpet, but there are five times as many pile threads D D as in tapestry carpet, and not more than one-fifth of the whole number of pile threads are raised simultaneously to form the shed for inserting the wire; the other four-fifths of the pile threads take the position of the thickening warp C in tapestry carpet. Some of the pile threads are only required to ascend and form loops at long intervals in the pattern, and the consumption of the same thread varies at different times according to the requirements of the pattern. Consequently a greater length of some pile threads is necessary than of others, and each pile thread therefore has here to be placed upon a separate bobbin; whereas for tapestry carpet all the pile threads are wound off a single long roller. The design in Brussels carpet is formed by the jacquard, each pile thread being of some particular colour throughout from end to end; and the jacquard draws up those threads which are of the colour required to produce the pattern.

In Fig. 14, Plate 104, is shown a longitudinal section of a Velvet or Cut-pile carpet. This is similar in construction to Brussels carpet, except that two shoots of weft are used to tie down each loop of the pile more securely; and the pile threads being woven over wires of deep section, as shown exaggerated in the diagram, the loops are afterwards cut open in withdrawing the wires, so as to form the velvet surface, as shown at E. The wires used for weaving velvet pile are shown full size in the side and edge views, Fig. 15, a knife F being formed at the outer end of each wire for the purpose of cutting open the loops in withdrawing the wire.

In Figs. 16 to 18, Plate 104, are shown diagrams of the three sheds required in weaving Brussels carpet. The shed in Fig. 16 is one for the shuttle, where all the pile threads D have been lifted as well as half of the body warp B, the other half of the body warp B being down; and the shuttle G then puts in the bottom shoot of weft that comes upon the back of the fabric. The shed shown in Fig. 17 is the next one formed, and is also for the shuttle, all the pile threads D being down, while the two halves of the body warp B B

remain in the same positions as previously; and the shuttle G then puts in the top shoot of weft, which ties down the loops formed upon the last wire inserted. The third shed, shown in Fig. 18, is for inserting the next wire A; here all the body warp threads B and pile threads D are down, except those pile threads that are lifted by the jacquard, which are to form the loops upon the new wire.

In the first attempt to apply self-acting machinery for working the wires, they were drawn out one by one as required from a bundle of wires, and were carried through the shed by a pair of nippers fixed at the end of a reciprocating rod; and after having been woven into the fabric and then withdrawn from the loops, the wires were returned by hand to the bundle. Next the whole operation was rendered self-acting, by dropping wires successively from a hopper into a longitudinal groove in a rod, which was pushed through the shed in guides, and was then caused to make a half revolution by means of a screw incline on the rod, so as to drop the wire into its place in the shed; and the wires were withdrawn successively from the fabric by reciprocating nippers, and carried up again into the hopper by endless chains. Afterwards an improvement was made by placing the wires singly in a trough, from which each in succession was pushed into the shed; and the wires were made with a hook at the back end of each, by means of which each was drawn out of the fabric successively by an endless chain, and was then transferred to the feeding trough for insertion again into the shed.

In the early application of machinery for working the wires, it was assumed that for wide fabrics, such as carpets, the wire could not be passed through the shed without being supported in its passage, on account of the deflection of its free extremity; various contrivances were therefore employed for supporting the wire as it passed through the shed, the wire being pushed from a trough used as a guide. It has since been found practicable however for the wires used in carpet weaving to be introduced without having supports in the shed; and this is done in the loom now extensively employed by Messrs. Crossley of Halifax, which comprises the important improvements of the late Mr. Collier. In this loom a

horizontal slide works in a long guide which is attached to arms fixed on a horizontal shaft below, so that the guide and the slide can be oscillated longitudinally in the loom between the positions for drawing the wire out of the fabric and inserting it again in the shed; the slide is made with a holder for holding the end of the wire. For drawing the wire out of the fabric a sliding hook is used, which is actuated by a crank; this hook takes hold of the bow on the end of the wire, and by the time it has drawn the wire nearly out of the fabric, the holder on the inserting slide has arrived opposite to it, and the end of the wire is jammed into the holder by the hook; the movement of the hook in the outward direction then ceases, but the sliding holder still continues its back movement until the wire is clear of the fabric and hook. When drawn out of the fabric the free end of the wire is received in a directing fork, which has an oscillating movement imparted to it longitudinally, corresponding with that of the oscillating frame carrying the inserting slide. The directing fork and the inserting slide then together carry the wire to the position for insertion into the shed; and during the time it is being inserted, they still continue their oscillating movement towards the wider part of the shed, until the wire is inserted to the full length. The inserting slide stands still while the wire is beaten up by the reed and bound in by the pile threads; after which it begins to slide outwards, releasing its hold of the wire, and at the same time the oscillating frame moves towards the point where the next wire is being withdrawn from the fabric, so that the sliding holder may be ready to receive the wire from the drawing-out hook in the manner already described. These movements are repeated for each wire inserted.

The arrangements previously referred to for working the wires in weaving pile fabrics have been for working a number of loose wires, where there are always ten to thirty wires or more remaining at the same time in the fabric during its manufacture: this method of working the wires is therefore known as the "loose wire" system. There is however another method of working the wires, called the "fast wire" system; and the first plan for working the wires on this system by self-acting arrangements in hand looms

for weaving narrow fabrics was invented in 1842 by Mr. Thompson of Coventry. Two wires are here used, one on each side of the fabric, and fixed at the outer end to arms or holders; these arms have successive movements whereby they withdraw each wire alternately from the fabric, then move it to the widest part of the shed and insert it in the shed, and then bring it back to the "fell" or point of beat up. At present however it is believed very few, if any, of this class of looms are employed. Manufacturers in general have an objection to looms in which only two wires are used, being of opinion that a good carpet pile fabric cannot be produced by that plan; and it may be presumed that this objection has some foundation, otherwise the improvers of this class of looms would not have departed from the simplicity of the two-wire loom by adding arrangements for working four wires, which render such looms very complex.

In the methods of working the wires on the loose-wire system there is considerable uncertainty in the mechanism, although it is probable that the various plans which have been described may all have been intended originally to act at very slow speeds; but it is rapid motion that developes the uncertainty and incorrect operation of the mechanism. In the improved loom about to be described however, which has been invented by the writer and made by Messrs. Sharp Stewart and Co., the previous defects are now so greatly diminished that the uncertainty of action may be considered to be entirely obviated. The new method of working the wires combines the advantages of both the systems previously described, namely the advantage of good quality in the fabric in consequence of using a number of wires, and also the advantage of the certainty of action belonging to the fast-wire loom, since the wires are never released or detached from the mechanism by which they are actuated. The movements of the wires are practically reduced to a simple reciprocation, as they may be considered to be virtually fixed in position.

This construction of mechanism for working the wires is known as the "roller wire-motion," and is shown in Figs. 1 to 11, Plates

98 to 103, in the improved form that is extensively used at the present time. Fig. 1 is a sectional side elevation of a Brussels carpet loom, showing the creel frames for the five sets of pile bobbins, the jacquard, and some of the principal parts of the loom. Fig. 2 is a longitudinal section of the loom to a larger scale; and Fig. 3 is a front elevation.

At the middle of the framing of the loom is the crank shaft C, Fig. 2, which actuates the "slay swords" or pair of arms B B carrying the reed S and the shuttle race G, and vibrating upon a shaft at the lower part of the frame of the loom: the position which the slay occupies at the "fell" of the fabric, when it has beaten up the weft or the wire, is shown by the dotted lines in Fig. 2. The cam shaft D is placed under the crank shaft C, and carries at one end the tappets from which the healds E are worked, Fig. 2, for lifting and depressing the threads forming the body warp of the carpet. Upon the cam shaft D are also fixed two arms F F carrying rollers, Fig. 3, which actuate through bell-crank levers the two picking arms H H; the free ends of these arms working through a slot in the shuttle-box give motion to the picker or shuttle. The comberboard I, Fig. 1, is carried by a pair of vertical sliding rods, one on each side of the loom, and receives the required up and down movement by means of a lever from a cam on the cam shaft D; the weight to be lifted by the comberboard is partly counterbalanced by weights on the tail end of the lever. The comberboard has as many holes in it as there are pile threads, and the cords J, Fig. 2, which actuate the pile threads pass through these holes, one through each; a knot which will not pass through the hole is made upon each cord a little above the comberboard, so that when the board is lifted all the pile threads are lifted together to form the shed for the bottom weft which crosses underneath the pile warp. The weights K suspended to the cords bring down each cord and its pile thread after it has been lifted. The jacquard L, Fig. 1, which is of ordinary construction, is actuated by a cam upon the cam shaft D; and the trap board lifts the successive selections of pile threads intended to form the loops upon the wires.

The five sets of pile threads are supplied from creels carried in the five creel frames M M, Fig. 1, each thread being wound on a

separate creel. A plan of one of the creel frames is shown to a larger scale in Fig. 4, Plate 101; and a side elevation, partly section, in Fig. 5. A weight for giving tension to the thread is hung upon each thread, between the creel and a wire over which the thread passes, as shown in Fig. 5. The body warp threads are placed upon the two long rollers N N at the end of the loom, Figs. 1 and 2, half the entire number of threads being upon each roller; and the threads are drawn off each roller over a smaller vibrating roller, which allows them to give way to the working of the healds E. The carpet newly woven is received upon a plate O, Fig. 2, extending across the loom, and then passes over a guide roller to the taking-up roller P, which is made of wood and studded with short spikes, so as to drag the carpet along as fast as it is woven, and deliver it to be wound upon the receiving roller Q placed below. This last roller is rotated by a ratchet-wheel and paul, which is actuated by a spring attached to one of the slay swords B; the use of a spring for this purpose prevents the possibility of winding up the carpet any faster than it is delivered by the spiked roller P.

The Roller Wire-Motion, or mechanism for working the wires, is fixed on one side of the loom, as shown at R R in the front elevation Fig. 3, Plate 100; and the construction of the mechanism is shown to a larger scale in Figs. 8 to 11, Plates 102 and 103. Figs. 8 and 9 are a front elevation and plan of the wire motion, showing one of the wires A in the act of being inserted into the shed of the fabric; and the plan shows a portion of the carpet already woven, and the reed S for beating up the weft or the wire. Fig. 10 is a transverse section, half full size, of the roller R in its casing E, with the slide T for inserting and withdrawing the wires; and Fig. 11 is an end elevation showing the arrangement for rotating the roller of the wire motion. Figs. 6 and 7, Plate 101, show a full-size side view and edge view of one of the wires.

The roller R and its casing E, Figs. 8 and 9, Plate 102, are rather longer than the width of the carpet to be woven; and the upper part of the casing E is cut away through the extent of one sixth of the circumference of the roller, as shown in Fig. 10. Six longitudinal

grooves are formed in the surface of the roller, of a width and depth corresponding to the diameter of the wires used. The roller in its casing is placed horizontally at one side of the loom, with its end about 9 inches from the edge of the carpet, and with the upper surface of the roller level and parallel with the "fell" of the fabric, as shown in Figs. 8 and 9. At that end of the casing nearest to the carpet, a recess is formed between the end of the roller R and a hoop I concentric with the roller; and in this recess, which extends through one sixth of the circumference of the roller, the heads of the wires are held when inserted in the fabric, as shown in the plan, Fig. 9, each wire having a head of the form shown in Fig. 6. The hoop I keeps the heads of the wires down in their places when inserted into the fabric, and prevents the wires from being pushed too far into the carpet; while the end of the roller prevents them from being withdrawn before the proper time. A projection upon the end of a spring J attached to the side of the casing keeps the heads of the wires erect, pressing them against each other and against the end of the recess, during the whole time that the wires remain inserted in the carpet. At the opposite or outer end of the roller R there is a projecting collar formed all round the roller, between the end of the casing E and a hoop carried by a bracket; and this collar has six grooves in it to receive the heads of the wires, so as to keep the heads in their correct radial position while being carried round by the roller in the direction shown by the arrow in Fig. 10. When the roller is stationary, two of its six grooves are opposite the two extreme wires in the recess I, Fig. 9: one being opposite the wire last inserted into the fabric, and the other opposite the wire next to be withdrawn from the carpet. The other four grooves have each a wire lying in them, as shown in Fig. 10, so that each time the roller is turned through one sixth of a revolution, one wire is brought round to the place for insertion into the shed of the fabric, and the wire last withdrawn from the carpet is carried away.

On the front of the casing E a slide-way is formed parallel to the axis of the roller R, Figs. 8 to 10, upon which is fitted a slide T, carrying the finger U for inserting the new wire, and the paul V for withdrawing the last wire. The finger U is hinged upon the

slide T by a spring joint, as shown in Fig. 10, so as to be held steady when either up or down. When down, as in Fig. 10, it slides against the inserting edge of the casing E; and a recess in the extremity of the finger fits over the head of the wire that is being inserted, so that as the slide T traverses inwards towards the carpet, the finger U pushes the wire forwards into the shed, holding it down all the time in the groove of the roller. When the slide arrives at the inner end of its traverse, nearest to the carpet, the paul V is tripped up by the head of the wire to be withdrawn, and drops on the inner side of the head, and the wire is then withdrawn from the carpet by the paul during the outward traverse of the slide T. In order to prevent the wire while being withdrawn from getting out of the groove in the roller R, several curved fingers K K are used, jointed to the underside of the casing E; the ends of these fingers cover the groove which receives the wire withdrawn, as shown by the dotted lines in Fig. 10, and each finger is pressed down upon the roller by a spring acting against the side of the hole through which the finger passes in the casing E. These fingers have to be lifted out of the way successively in order to allow the head of the wire to pass; and this is done by a double incline L upon the bottom of the slide T, which acts upon the projecting tail of each finger in succession during the traverse of the slide.

The slide T receives its traversing motion from a rope X, Figs. 8 and 9, which is secured in a hole in the slide by a block and set screws, Fig. 10; this rope passes over guide pulleys at the ends of the roller casing E, and then to the pulley Y, Fig. 3, to which the two ends of the rope are secured. The shaft of the pulley Y carries a pinion gearing with the toothed sector W, which is centred at the top in the framing of the loom, and is worked backwards and forwards by a drum cam upon the cam shaft D, Fig. 3. This cam is shaped to produce a quick forward traverse of the slide T, so as to insert the wire quickly while the shed is held open for it; but the cam gives a slower backward traverse to the slide, so as to withdraw the wire slowly, having more time to do this in, as a wire is inserted only at every third shed.

After each wire has been inserted in the fabric, the wire roller R, Fig. 10, is turned round through one sixth of a revolution in the direction of the arrow, by means of the mechanism shown in Fig. 11, Plate 103. The cam M, Figs. 3 and 11, on the end of the cam shaft D of the loom, gives motion to a lever oscillating upon a centre in the framing of the loom; and the other end of this lever has a forked paul jointed to it, which is kept pressed by a spring against the pins in the disc N secured upon the end of the wire roller R, Figs. 8 and 9; the extent of movement of the lever and paul is shown by the dotted lines in Fig. 11. The wire roller is held steady after each turn by a T piece sliding vertically, which is pressed upwards by a spring against the pins in the disc N, as shown in Fig. 11.

The wires lying in the grooves of the roller previous to insertion into the fabric project 2 or 3 inches beyond the inner end of the roller; and if the point of the wire went straight forwards, as pushed from the groove in the roller, it would be impossible to make it enter the shed correctly, as it would then be so close to the "fell" of the fabric or angle of the shed that the point of the wire would inevitably catch the threads forming the shed. The wire is consequently sprung or deflected upwards and to one side, as shown at A in Figs. 3, 8, and 9, by means of the short grooved guide Z, through which the wire passes as it is pushed out of the roller groove. The guide Z is fixed upon the top of a vertical rod, which is moved up and down by a lever actuated by a cam; and when the wire has been pushed nearly through the shed, the guide is lowered into the position shown by the dotted lines in Fig. 8, so as to be out of the way of the wire at the moment of its being beaten up by the reed; after which the guide is lifted again, so as to be ready for the insertion of the next wire. The springing of the wires by the guide in directing them into the shed might at first sight appear objectionable; but the amount of this bending does not exceed what they will recover by their own elasticity, and the experience of working during many years has proved it to be a great advantage, because the bending stiffens the wire and makes its point steadier whilst passing through the shed. Besides this, in consequence of the angle at which the guide causes the wire to enter the shed, the

point of the wire comes into a wider part of the shed the further it passes through the shed; and thus, as the unsteadiness of the point of the wire increases with the greater length unsupported in the shed, more space is allowed for its vibration, without risk of its catching the threads forming the shed.

Owing to the position of the roller wire-motion at one side of the loom, the shuttle-box on that side has to be made detached from the slay B B, Figs. 2 and 3, and carried by separate "slay swords" which oscillate upon a shaft coinciding with the shaft for the slay B B. This loose shuttle-box is actuated by a cam upon the crank shaft C of the loom, which acts upon a roller in a rod jointed at one end to the shuttle-box; the other end of the rod is slotted to slide upon the crank shaft as a guide. The cam is shaped so as to actuate the loose shuttle-box in such a manner that it will come opposite to the slay B B and have a motion identical with it at the time the shuttle is passing across the shed.

This loom will weave 3 inches of carpet per minute, and as much as 47 yards has been woven in one day of ten hours, including stoppages. The average production per day of ten hours is 42 yards of carpet, which is an important increase over the production of the previous constructions of looms.

Mr. Weild exhibited a specimen of the roller wire-motion, showing its action, with samples of the different kinds of wires used.

Mr. C. W. Siemens enquired how long this motion had been in use in carpet looms.

Mr. Weild replied it had been at work for twelve years, and was now extensively used, having been found superior to the other plans both in the speed at which it could be worked, on account of the certainty of its action, and also because it was free from the liability of the wire missing its course when passed into the shed and getting its

end pushed up through the warp. The wires were held firmly in the grooves of the roller by the series of curved fingers, which were successively lifted and dropped again in the passage of the slide by the inclined plane upon the slide; and whilst the wire was being passed into the shed it was held firmly all the time at the back end by the spring finger of the slide, and the free end of the wire was steadied by being sprung on one side by the grooved guide, which stiffened the wire at the time by the elastic strain put upon it; by this means the free end was so well steadied as to prevent the risk that occurred in other looms of its catching the warp threads, although this loom was worked at a higher speed. The side springing of the wires did not strain or bend them permanently, as they were of hard steel and very carefully made.

Mr. W. Richardson asked what was the difference of speed, and how many yards per day could be woven by hand looms.

Mr. Weild replied that this loom put in 27 wires per minute as compared with 21 per minute in the other looms; but in hand weaving the speed was only about 3 to 4 wires per minute.

Mr. W. Richardson enquired whether the roller motion laid the wires in quite as regularly as hand work; and whether the same motion was suited to the work of all looms.

Mr. Weild replied that the regularity of the machine work was perfect in laying the wires and beating them up; and one pattern of machine suited all looms, because there was one standard make for all Brussels carpets, namely 8 wires per inch of length, and 27 inches width of carpet. The difference in the work involved in the carpets was in the number of coloured threads used in the pile warp for forming the pattern, and in the best carpets these amounted to the immense number of 1300 threads, all of which had to be brought up to the surface in turn and all kept in order. About one fifth of the whole number had to be picked up by the jacquard at each insertion of a wire, to ensure the wire being completely covered all across the fabric. There were also the threads of the body warp to be added, for forming the foundation of the fabric; and these raised the total number of threads to about 1700 in the best carpets, each one of which had to be passed through an

eye in a separate cord, so as to be picked up individually whenever required.

The CHAIRMAN asked what attendance a loom required in working.

Mr. WEILD replied that one man attended to one loom, and a boy attended to the creels of two looms, his business being to change the spools of warp threads as they became emptied.

The CHAIRMAN remarked that it was a very ingenious and interesting piece of machinery which had been described; and he moved a vote of thanks to Mr. Weild for his paper and the specimens exhibited, which was passed.

The CHAIRMAN proposed a vote of thanks, which was passed, to the Honorary Local Secretaries, Mr. John Fernie and Mr. W. E. Marshall, for the excellent arrangements they had made for the meeting of the Institution in Leeds; and also to the authorities of the Philosophical Hall for their kindness in granting the use of the Lecture Theatre for the purpose of the meeting; and to the several Railway Companies for the special facilities they had so kindly afforded to the Members for attending the Meeting in Leeds and the Excursions in connection with the meeting.

The Meeting then terminated.

In the afternoon an Excursion was made by the Members by special train to the Works of Messrs. Titus Salt, Sons, and Co., at Saltaire, where the new Corliss Engines were seen at work; and the Members were very handsomely entertained at the Works by Mr. George Salt, and returned to Leeds in the evening.

On Thursday, 30th July, the Members visited the Tingley Colliery, where the two different Coal-Cutting Machines described at the Meeting—the Pick and the Straight-action Machine—were both seen at work in the pit. The Shale Oil Works and Brick Machinery at Tingley and the new Blast Furnaces at Ardsley, belonging to the West Yorkshire Coal and Iron Company, were also shown to the Members.

The Members also visited the Steam Plough and Locomotive Works of Messrs. John Fowler and Co. in Leeds, where the new Wire-Rope Travelling Crane described at the Meeting was seen at work.

On Friday, 31st July, an Excursion was made by the Members by special train to Scarborough, visiting at York on the way the new Lendal Iron Bridge and the Minster; and they were invited to Dinner in the evening by the Local Committee at the Grand Hotel, Scarborough, in celebration of the Leeds Meeting of the Institution.

FRICTION COUPLING AND BREAK. *Plate 105.*

Fig. 1. *Model illustrating multiplication of frictional surfaces.*

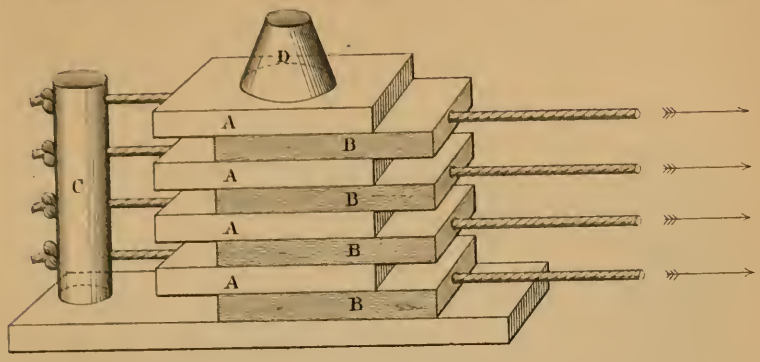
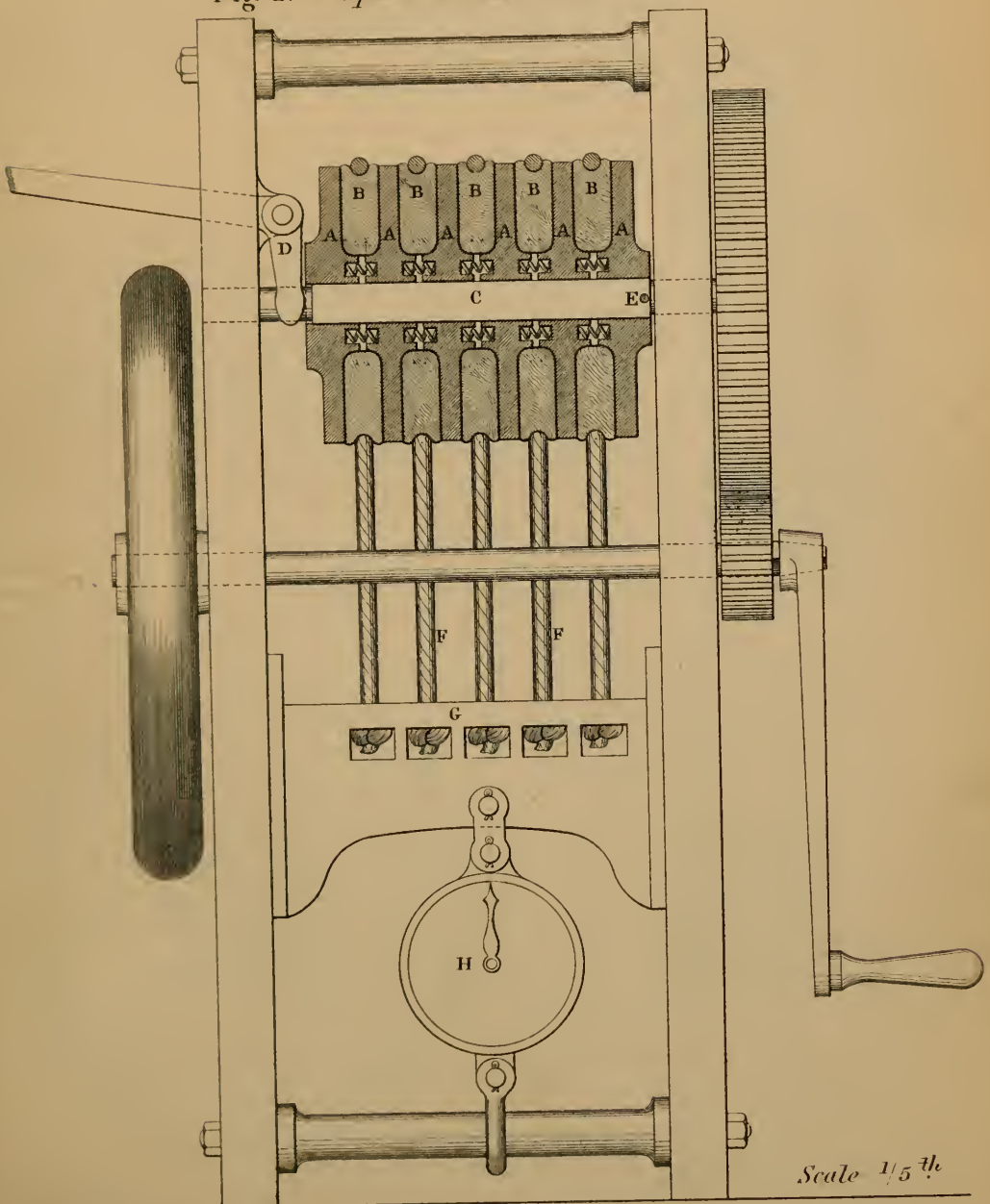


Fig. 2. *Experimental Disc Break.*



Scale 1/5th

(Proceedings Inst. M. E. 1868.)

FRICTION COUPLING AND BREAK. *Plate 106.*

Six-ton Hoisting Crab.

Fig. 3. *Longitudinal Section.*

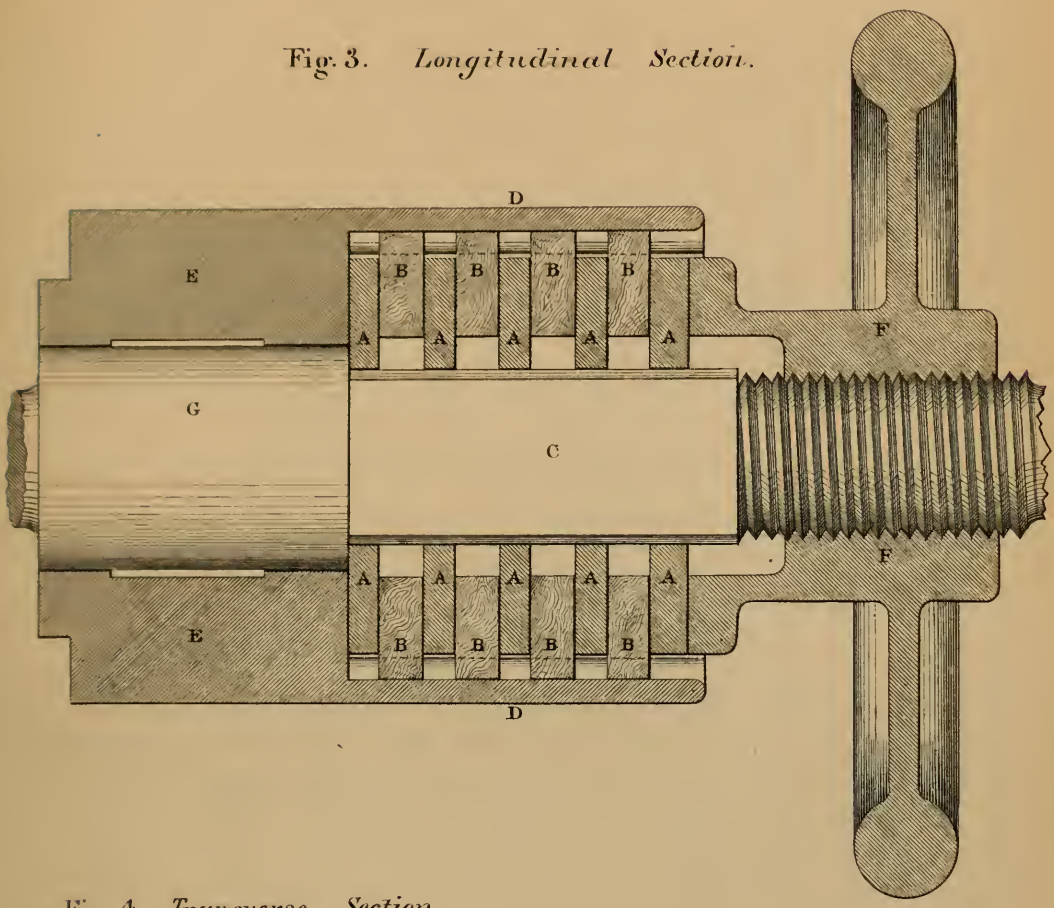


Fig. 4. *Transverse Section showing Wood Disc.*

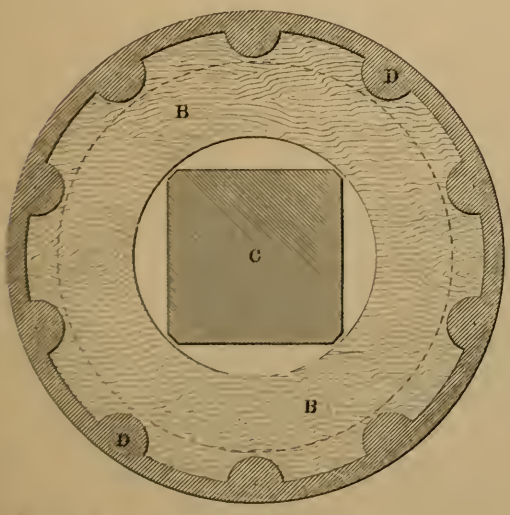
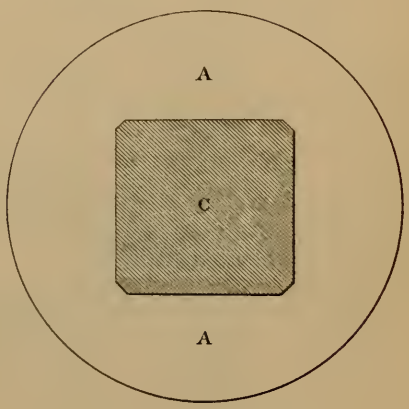


Fig. 5. *Transverse Section showing Iron Disc.*



(Proceedings Inst. M. E. 1868.)

Scale 1/3rd

0 1 2 3 4 5 6 7 8 Inches.

FRICTION COUPLING AND BREAK. *Plate 107.*

Sack Hoist,

stopped by rope in lowering,

for quick lowering.

Fig. 6. *End Elevation. Scale 1/10th*

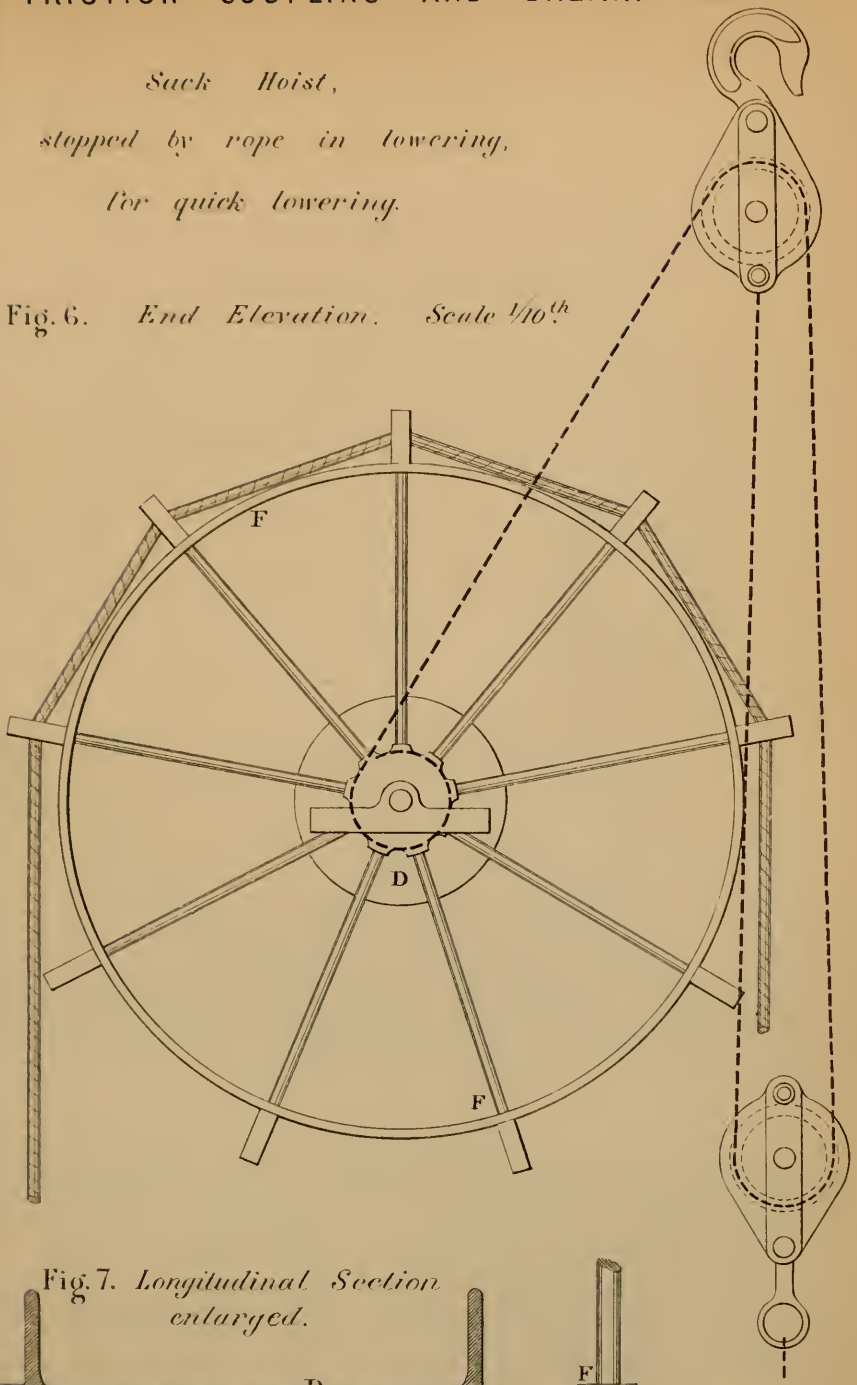
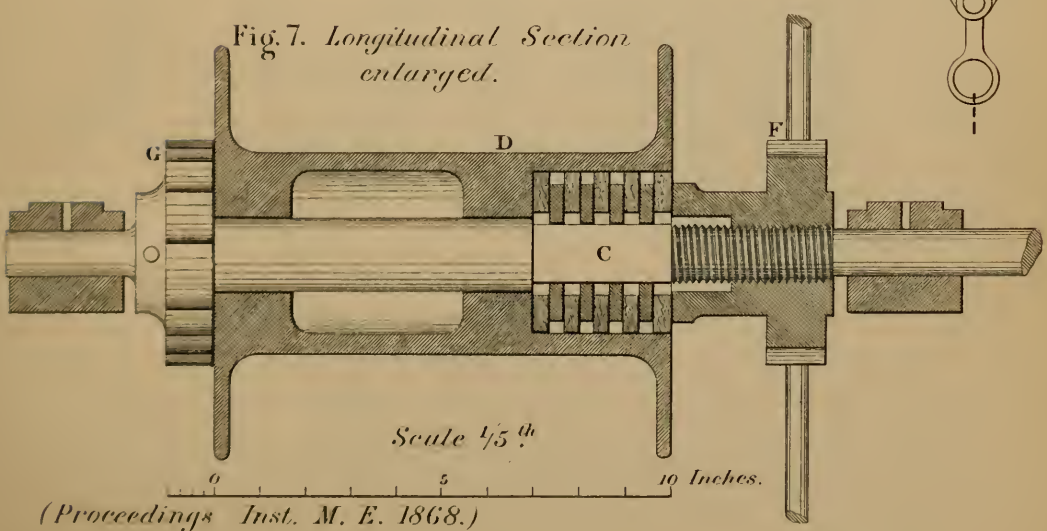


Fig. 7. *Longitudinal Section enlarged.*

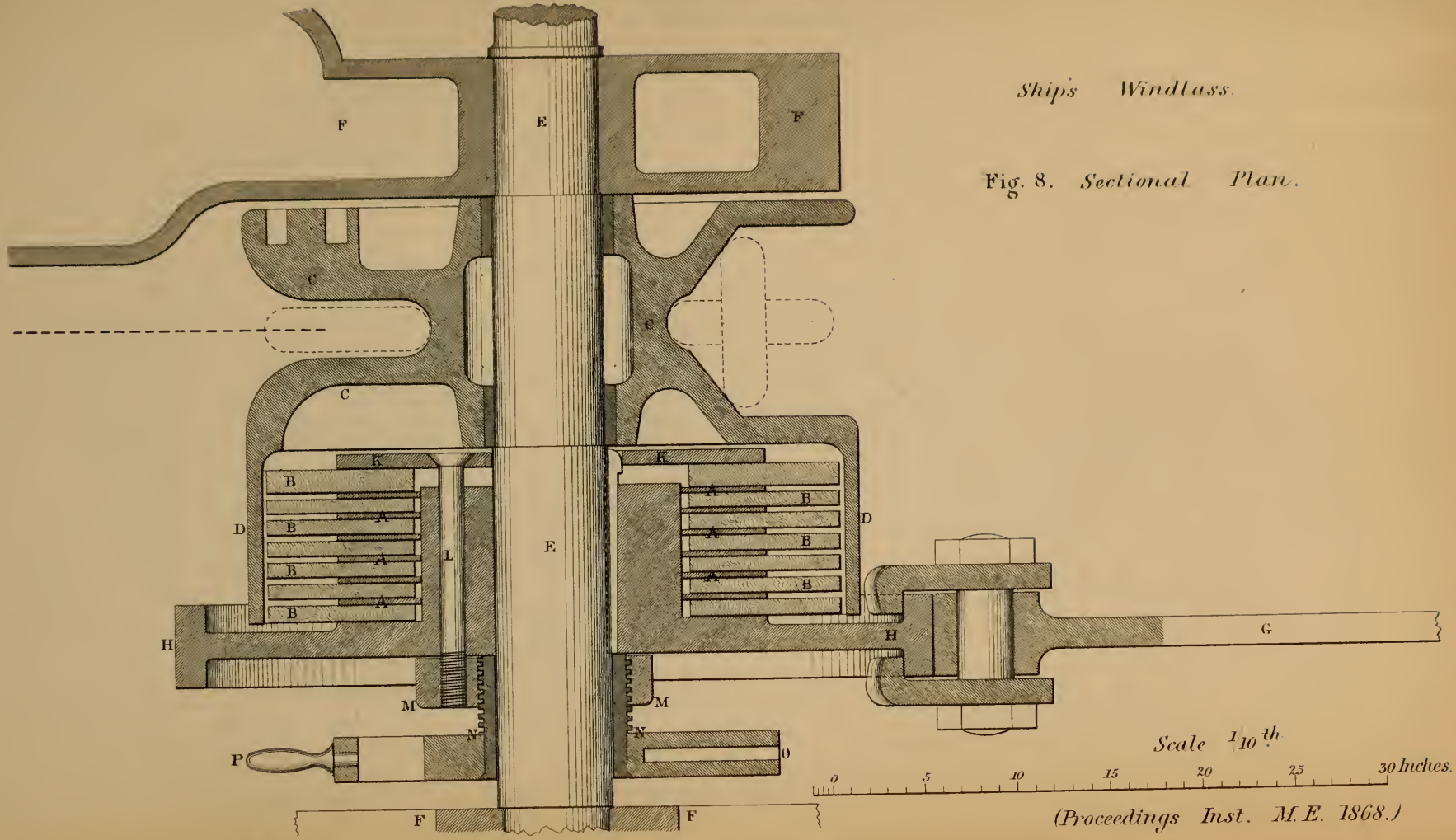


(Proceedings Inst. M. E. 1868.)

FRICTION COUPLING AND BREAK.

Ships Windlass.

Fig. 8. *Sectional Plan.*

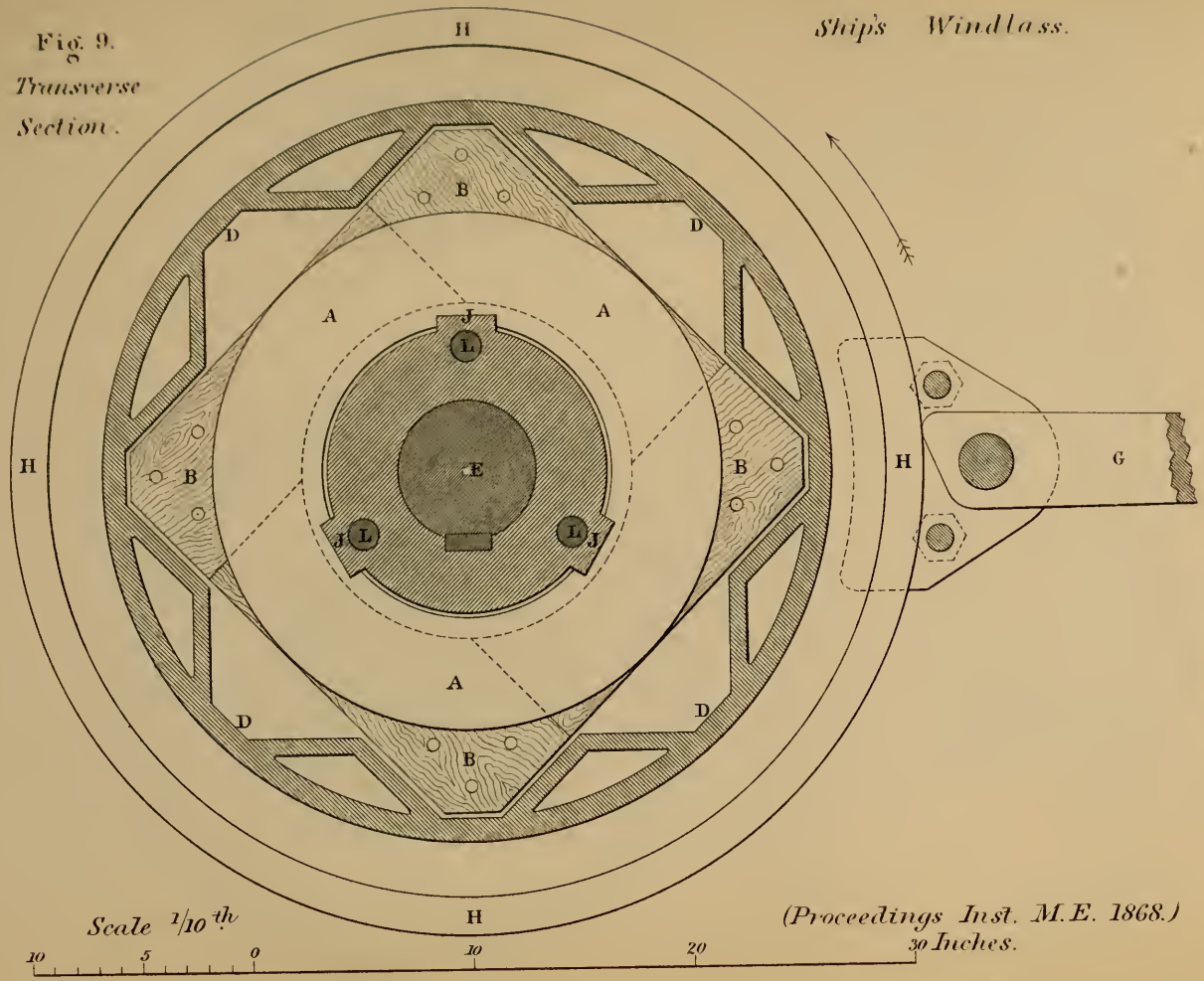


(Proceedings Inst. M.E. 1868.)

FRICTION COUPLING AND BREAK.

Fig. 9.
Transverse Section.

Ship's Windlass.



(*Proceedings Inst. M.E. 1868.*)

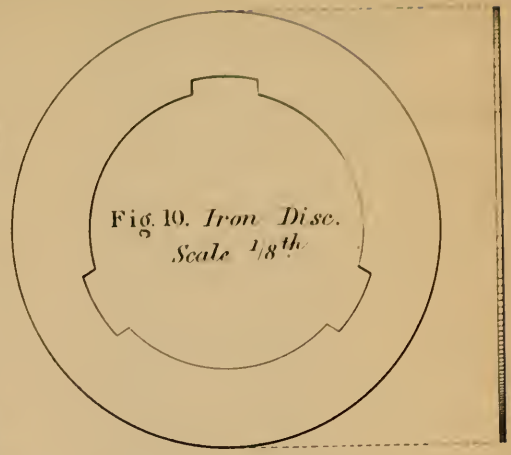


Fig. 10. *Iron Disc.*
Scale 1/8th.

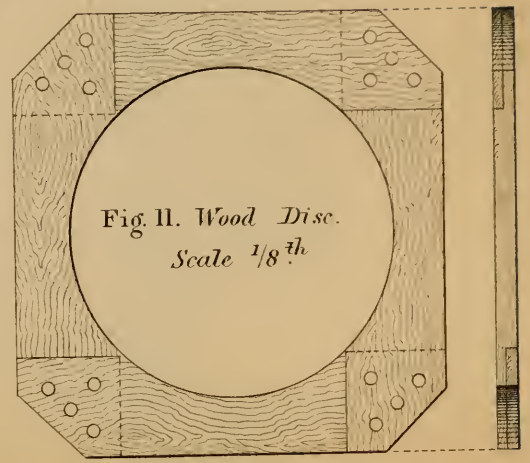


Fig. 11. *Wood Disc.*
Scale 1/8th.

Shaft Coupling.

Fig. 12. *Longitudinal Section.*

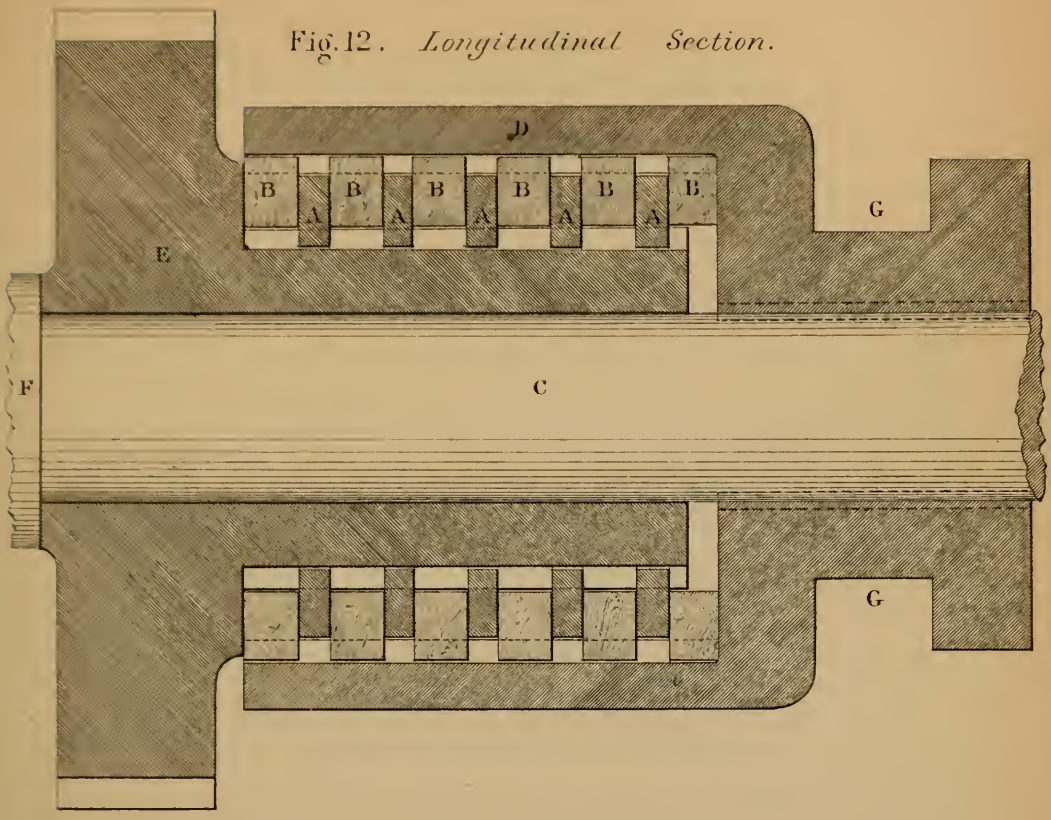


Fig. 13.
Transverse Section shewing Iron Disc.

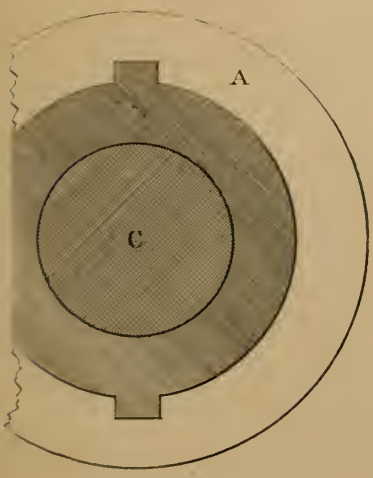
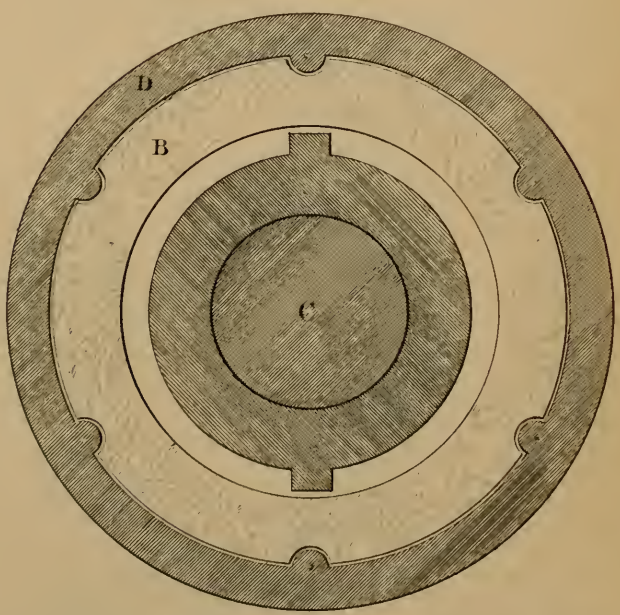
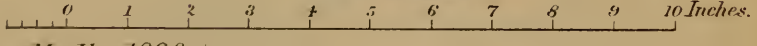


Fig. 14. *Transverse Section shewing Wood Disc.*



Scale 1/4 *th*



(Proceedings Inst. M. E. 1868.)

FRICTION COUPLING AND BREAK. *Plate III.*

Safety Clutch.

Fig. 15. *Longitudinal Section.*

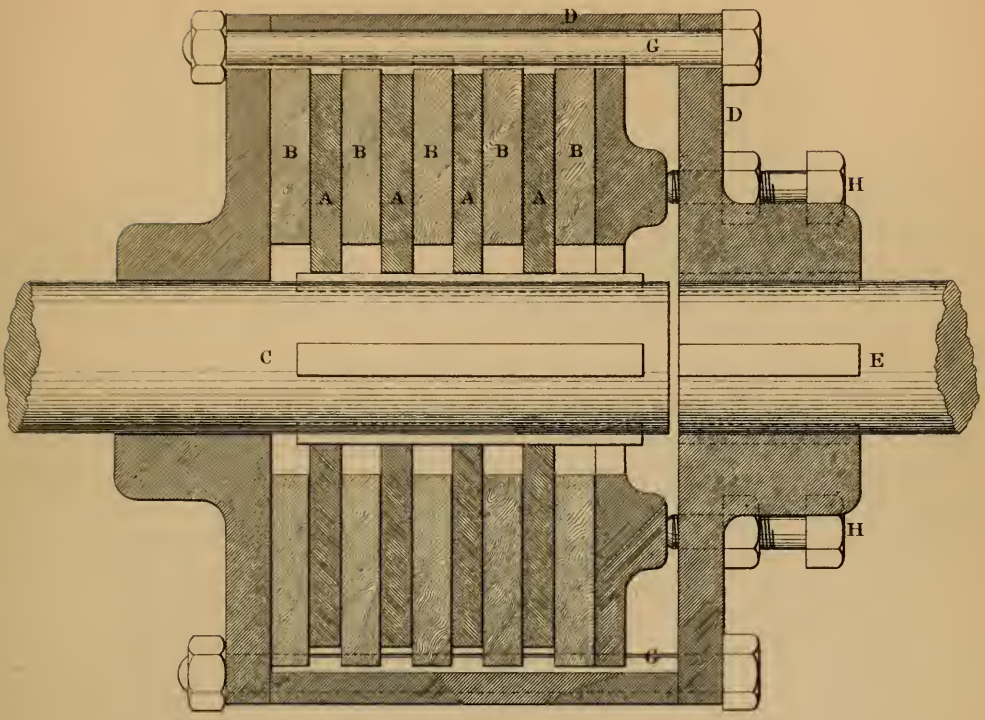
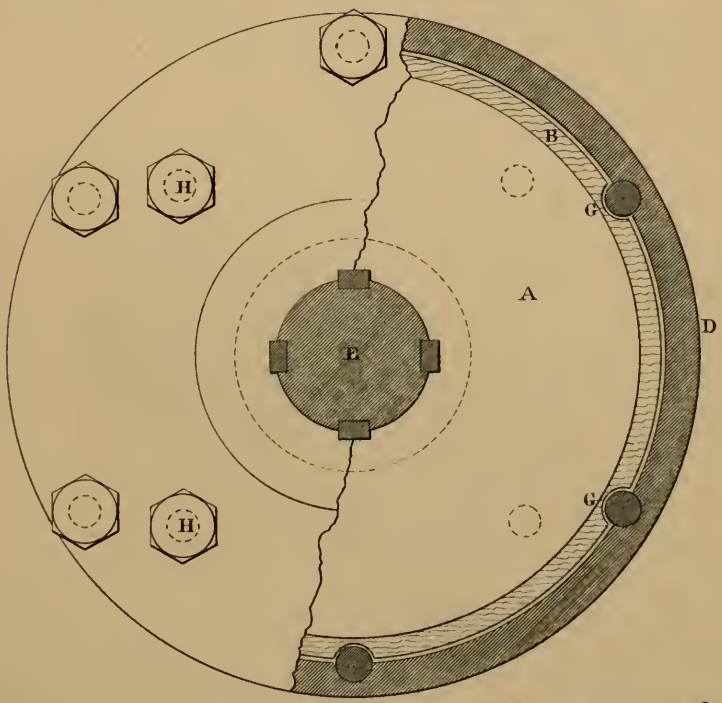


Fig. 16. *End Elevation and Transverse Section.*



(Proceedings Inst. M.E. 1868.)

Scale 1/4 *th*

0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

FRICTION COUPLING AND BREAK. *Plate 112.*

Self-engaging Shaft Coupling.

Fig. 17. *Longitudinal Section.*

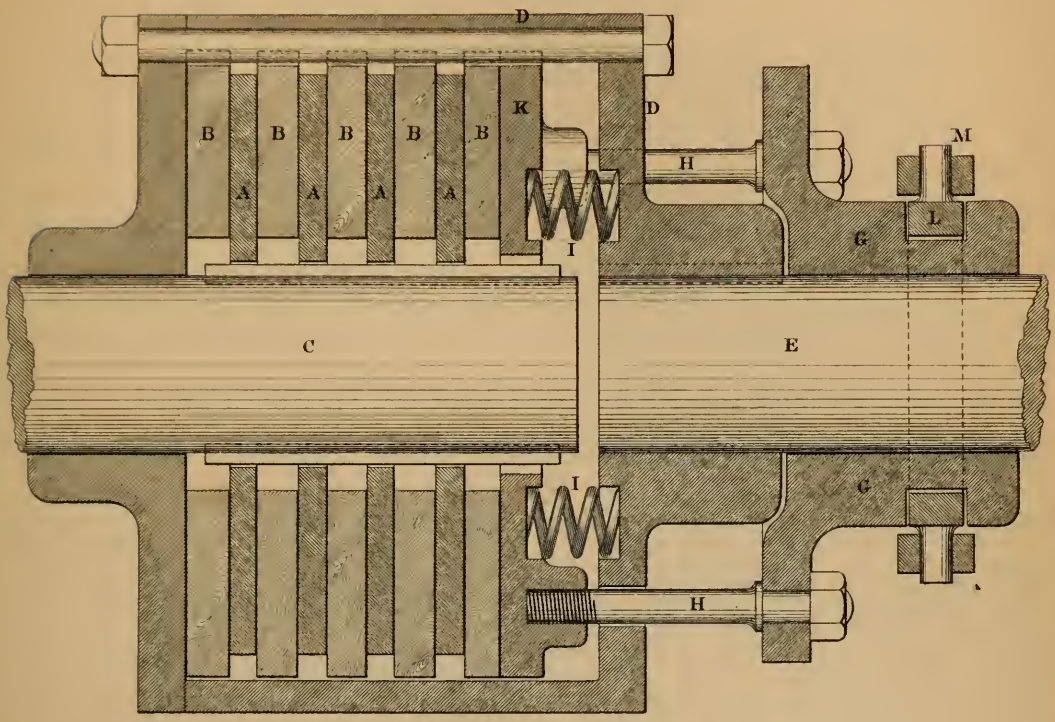
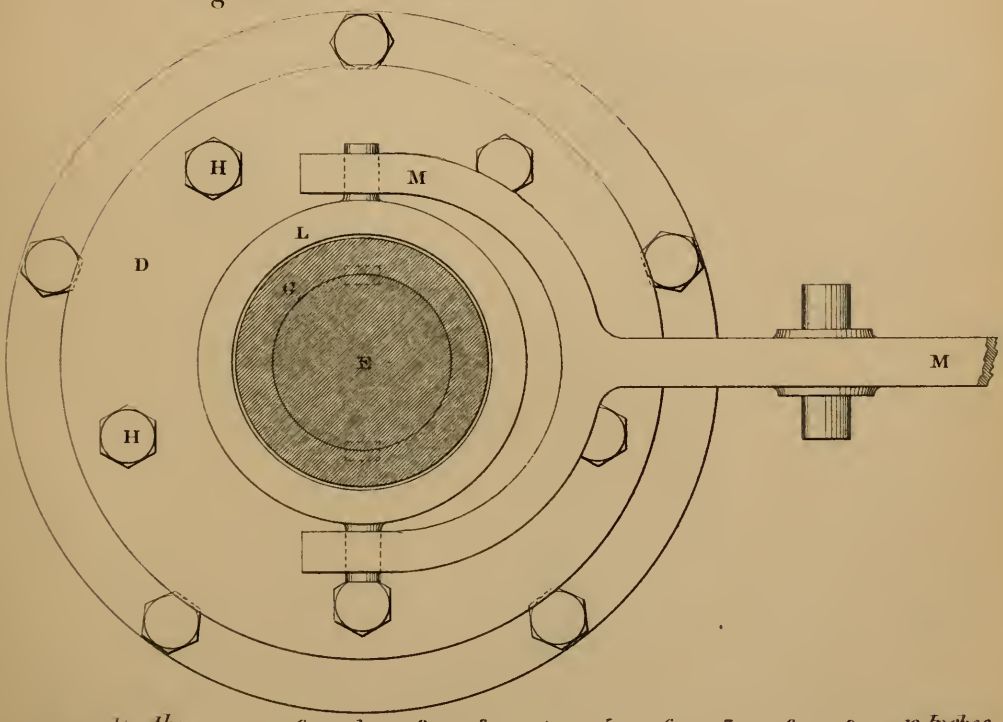


Fig. 18. *End Elevation.*

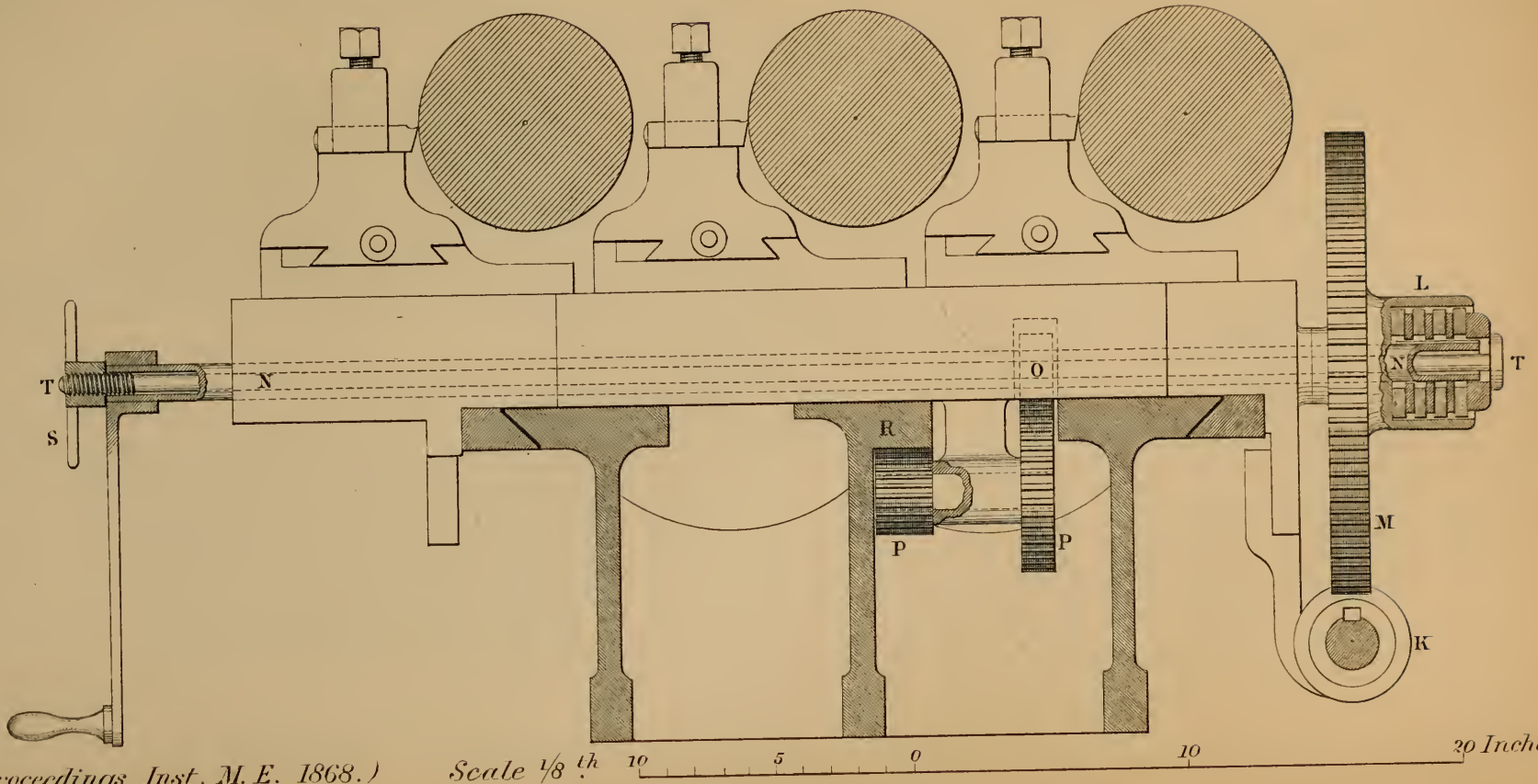


Scale 1/4 th 0 1 2 3 4 5 6 7 8 9 10 Inches.

(Proceedings Inst. M.E. 1868.)

FRICTION COUPLING AND BREAK.

Fig. 19. *Lathe Coupling.*



(Proceedings Inst. M. E. 1868.) *Scale 1/8 th*

FRICTION COUPLING AND BREAK.

Plate 114.

Fig. 20. *Longitudinal Section.*

Safety Pinion.

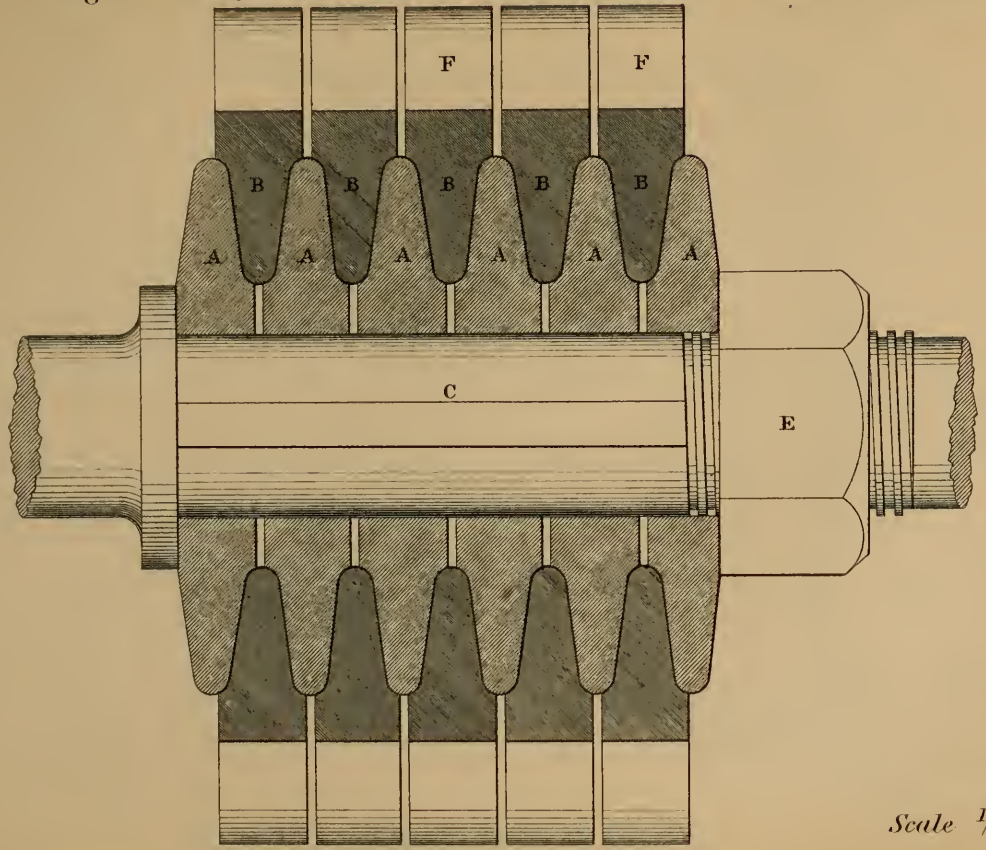
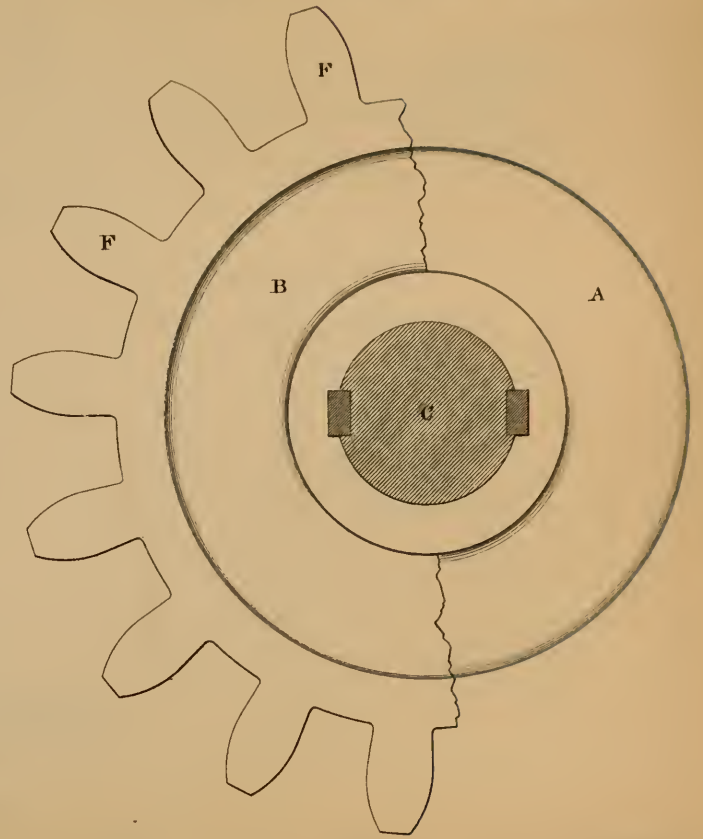


Fig. 21. *Transverse Section.*



Scale 1/5 th

0 5 10 15 20 Inches.

(Proceedings Inst. M. E. 1868.)

FRICTION COUPLING AND BREAK. *Plate 115.*

Sack Hoist.

lowered by rope continuously.

for slow lowering.

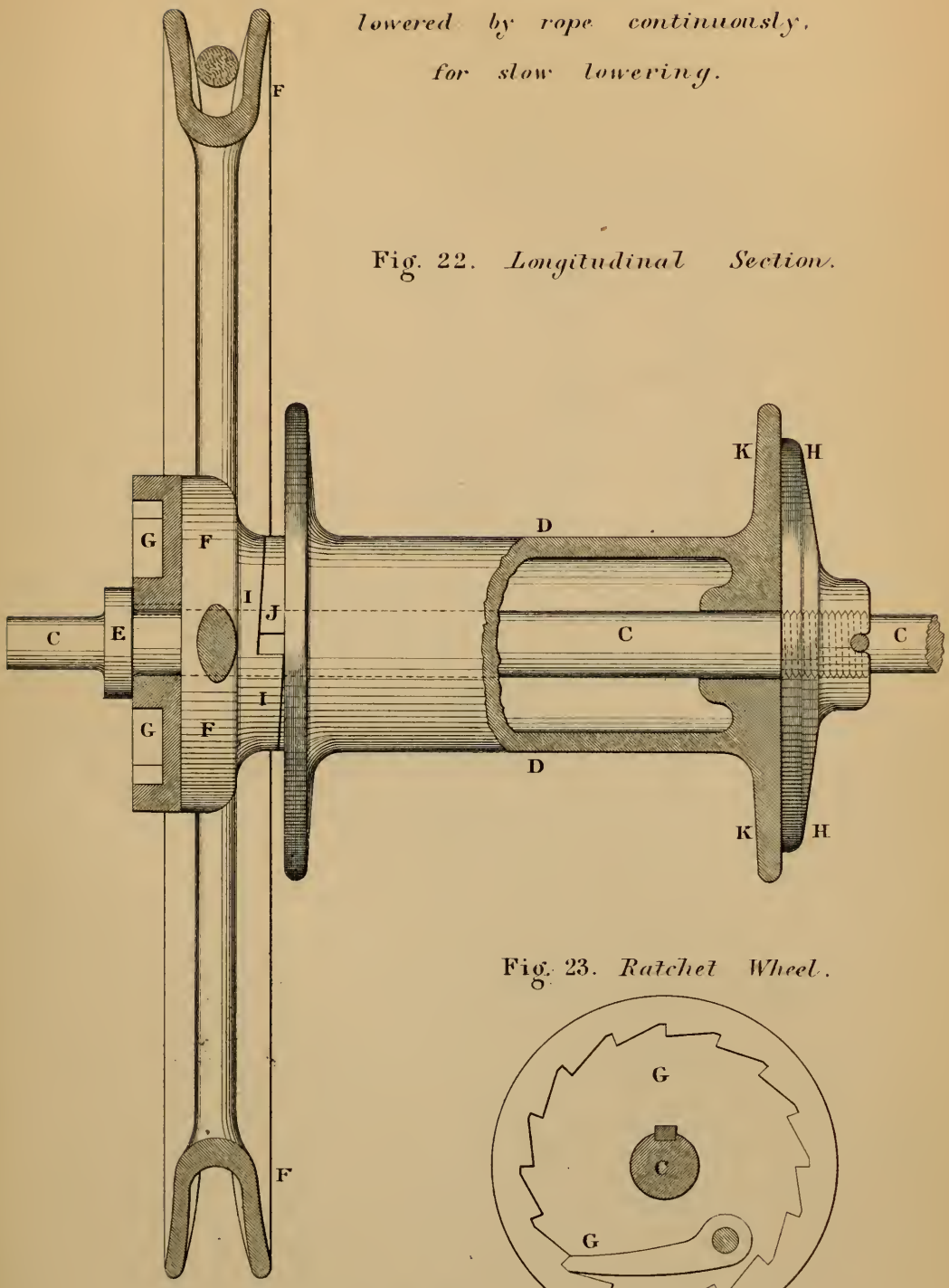
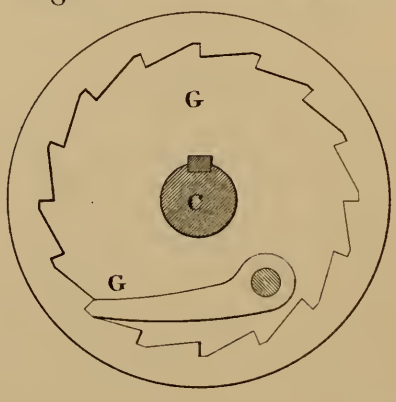


Fig. 22. *Longitudinal Section.*

Fig. 23. *Ratchet Wheel.*



Scale $\frac{1}{4}$ *th*

0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

(Proceedings Inst. M.E. 1868.)

FRICTION COUPLING AND BREAK.

Plate 116.

Bracket Winch, lowered by handle continuously, for slow lowering.

Fig. 24. *End Elevation.*

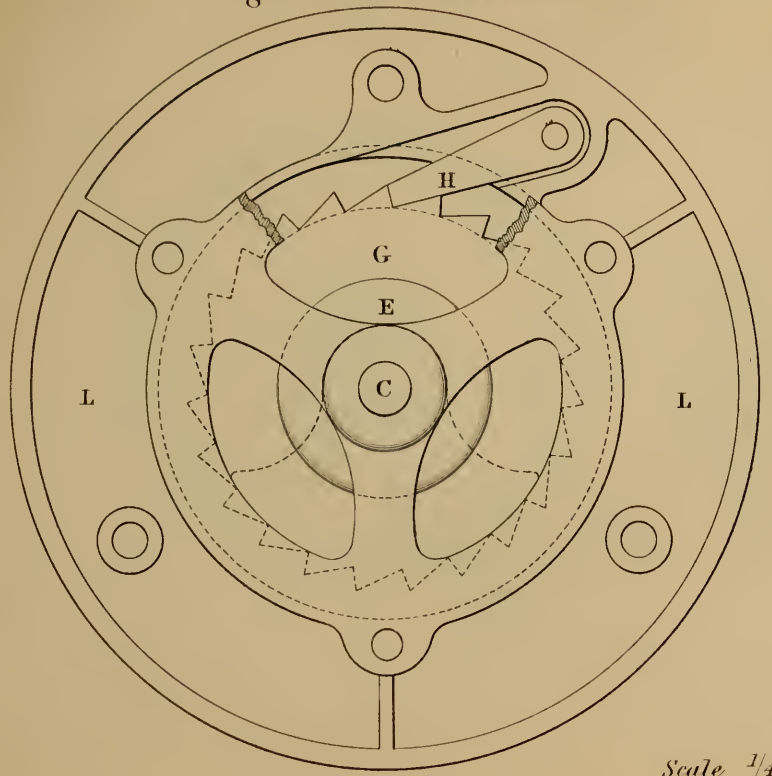
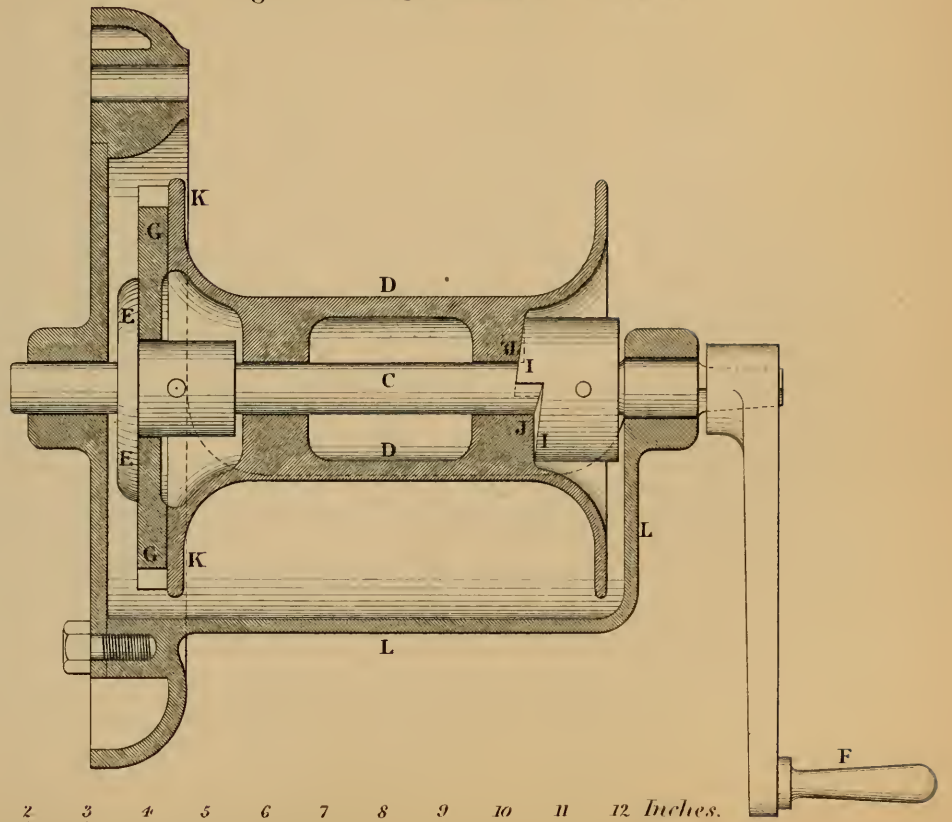


Fig. 25. *Longitudinal Section.*



Scale 1/4 th

0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

(Proceedings Inst. M.E. 1868.)

Fig. 26. *Hoisting Crab, lowered by handle continuously, for slow lowering.*

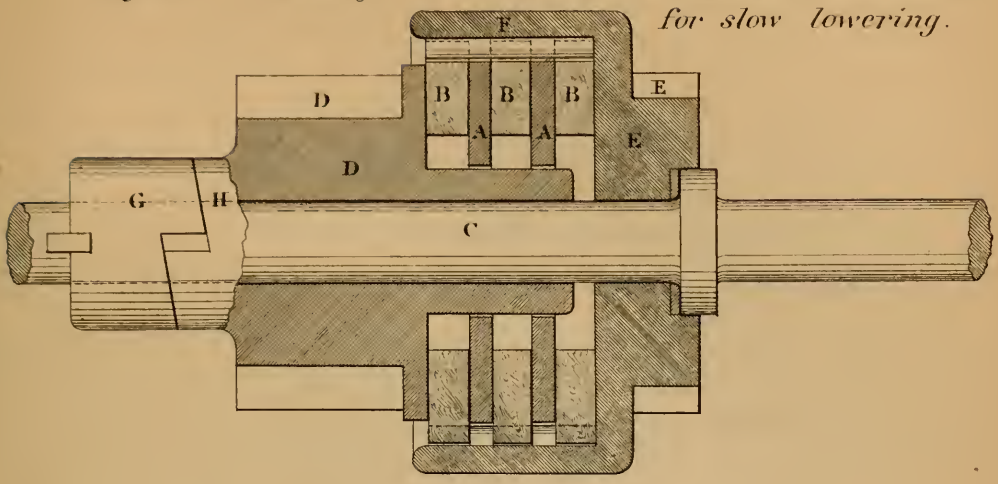


Fig. 27. *Hoisting Crab, stopped by handle in lowering, for quick lowering.*

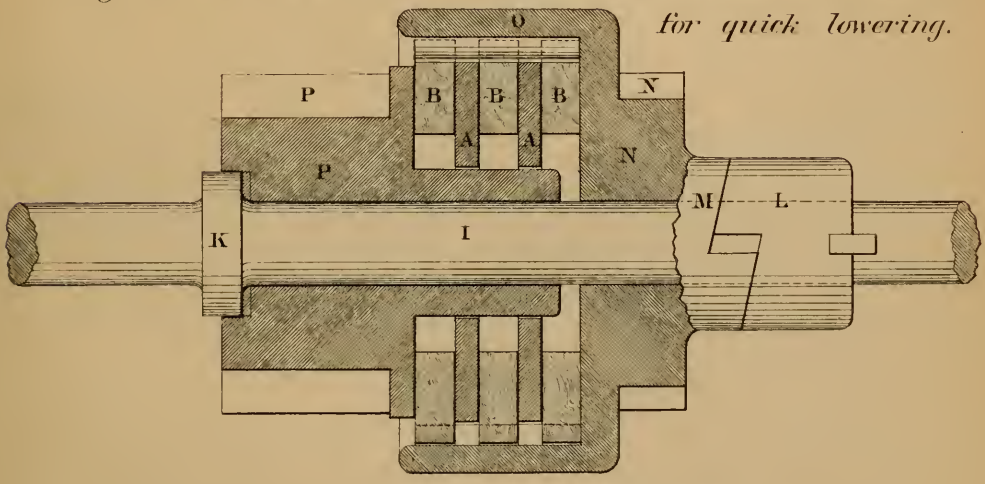
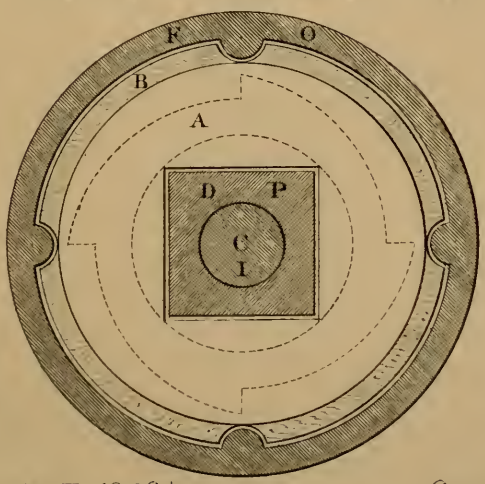


Fig. 28. *Transverse Section of both Crabs.*



(Proceedings Inst. M. E. 1868.) *Scale 1/3rd*

0 1 2 3 4 5 6 7 8 9 10 *Inches.*

WHEEL MOULDING MACHINE. *Plate 118.*

Fig. 1. *End Elevation of Moulding Machine.*

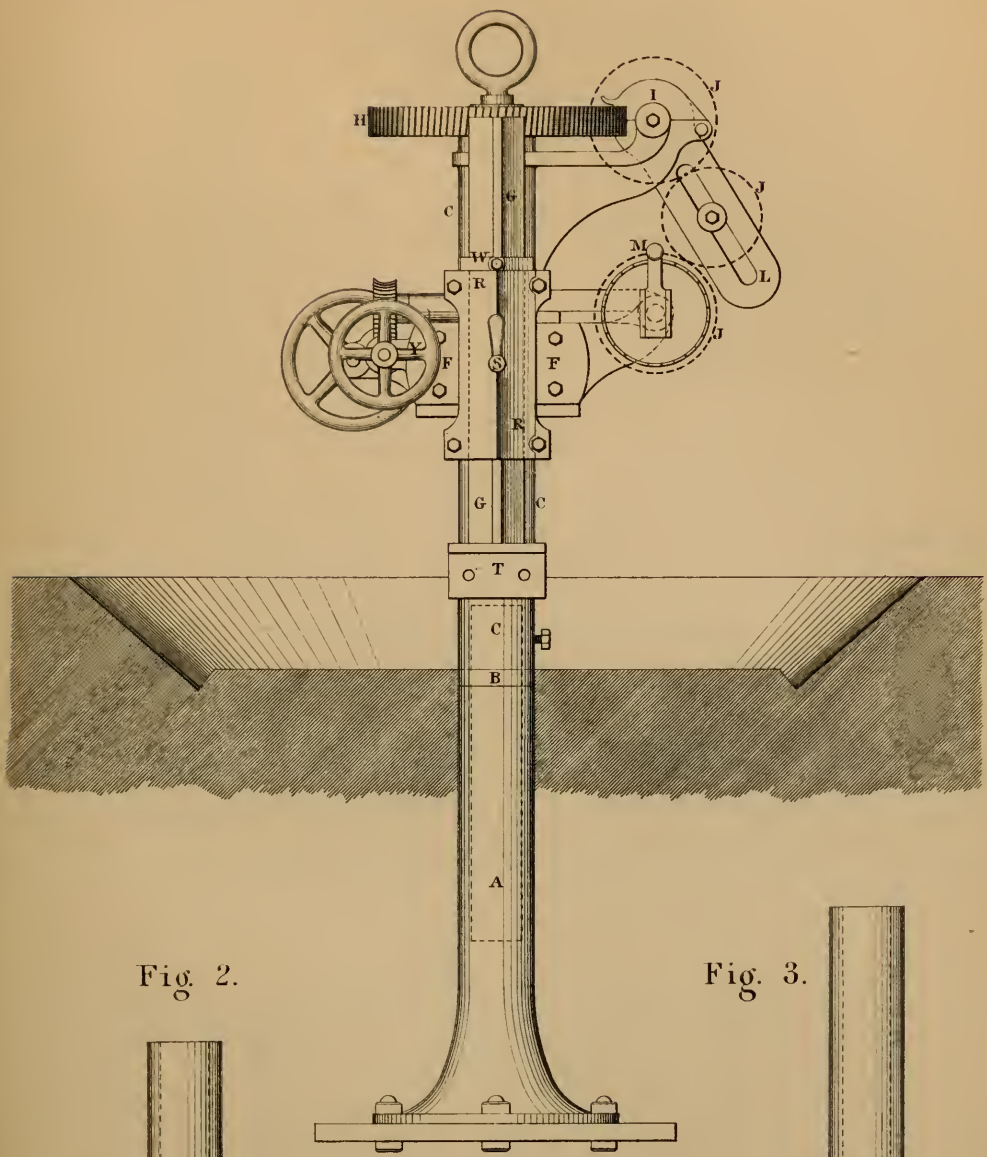


Fig. 2.

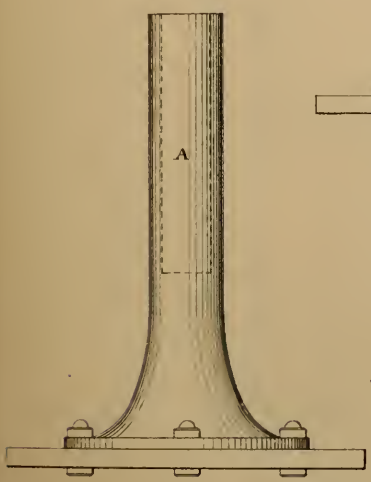


Fig. 3.

Scale 1/15 *th*

(Proceedings Inst. M.E. 1868.)

Fig. 4. *Side Elevation of Moulding Machine.*

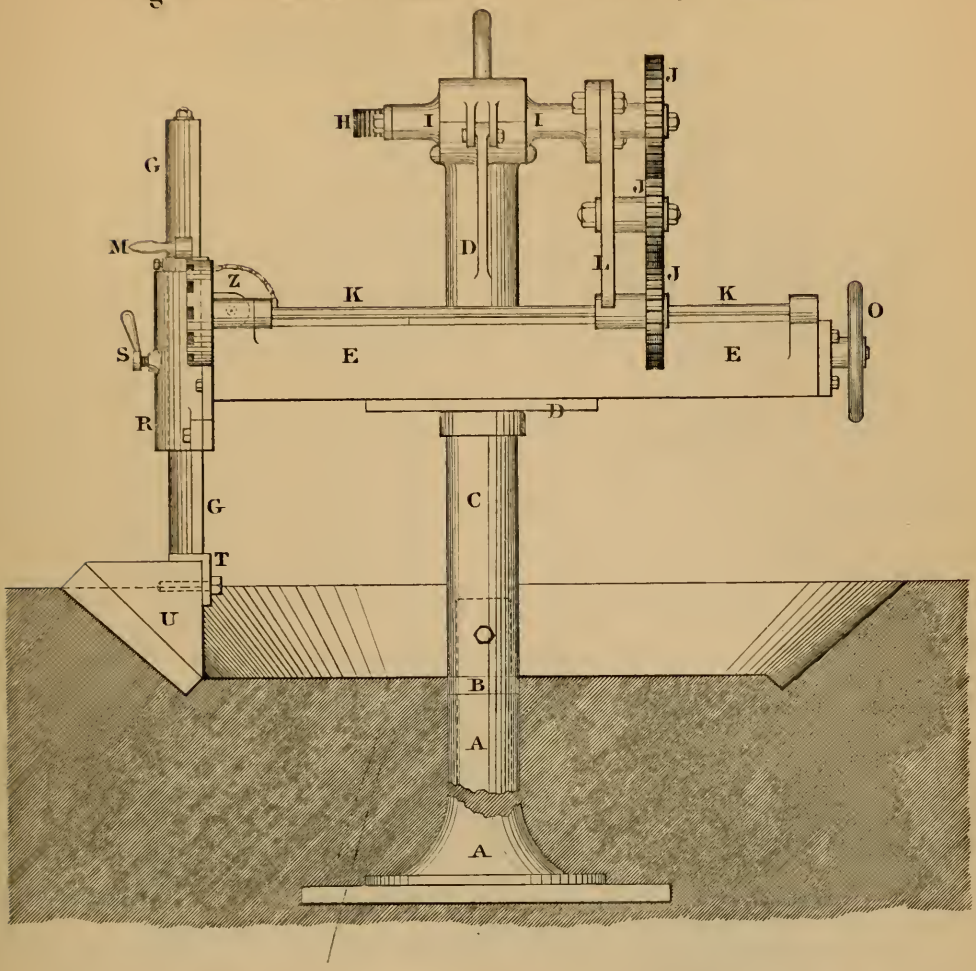
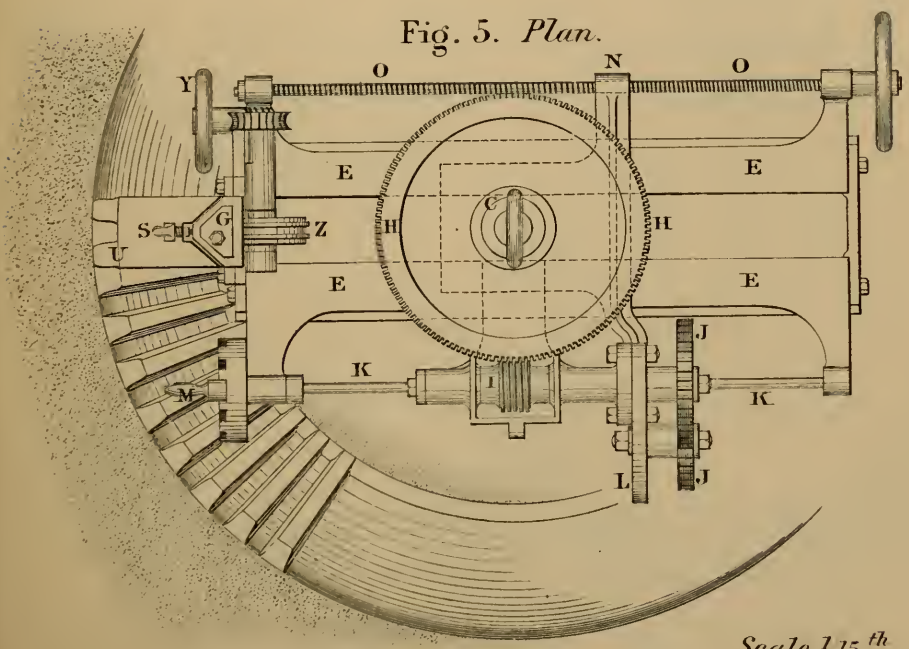


Fig. 5. *Plan.*



Scale 1/15th

(Proceedings Inst. M.E. 1868.)

0 10 20 30 Inches.

Fig. 6.

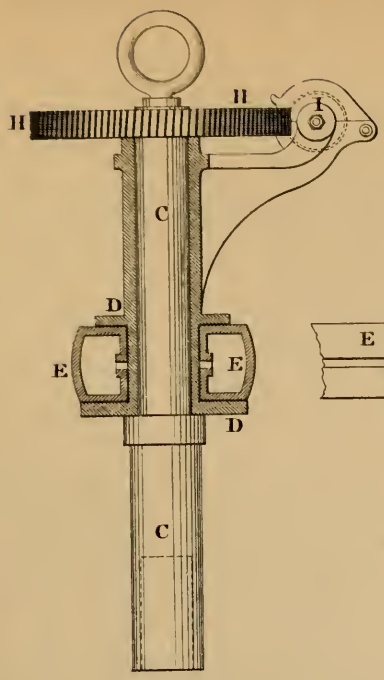


Fig. 7.

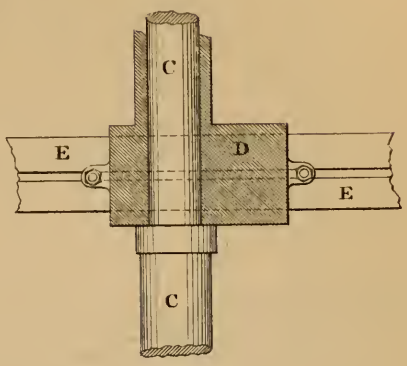


Fig. 8.

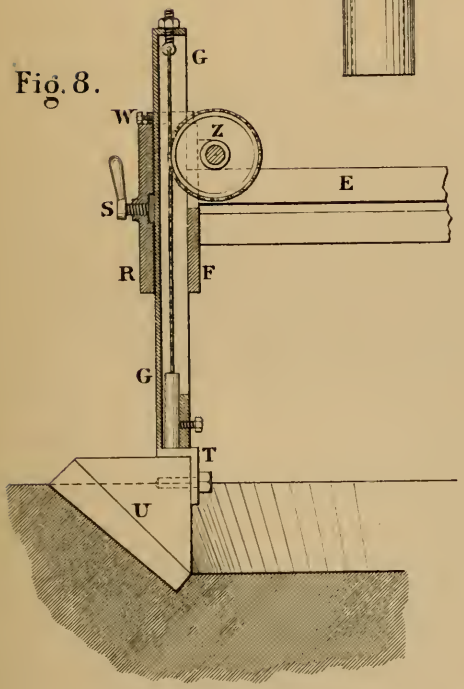


Fig. 9.

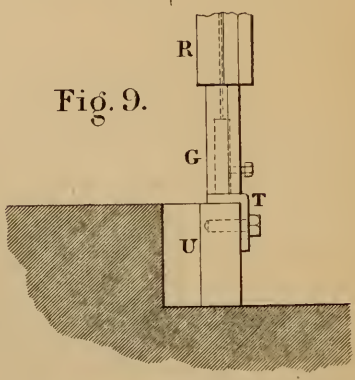


Fig. 10.

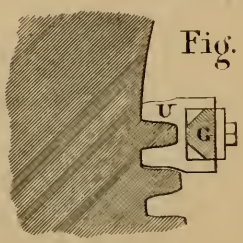
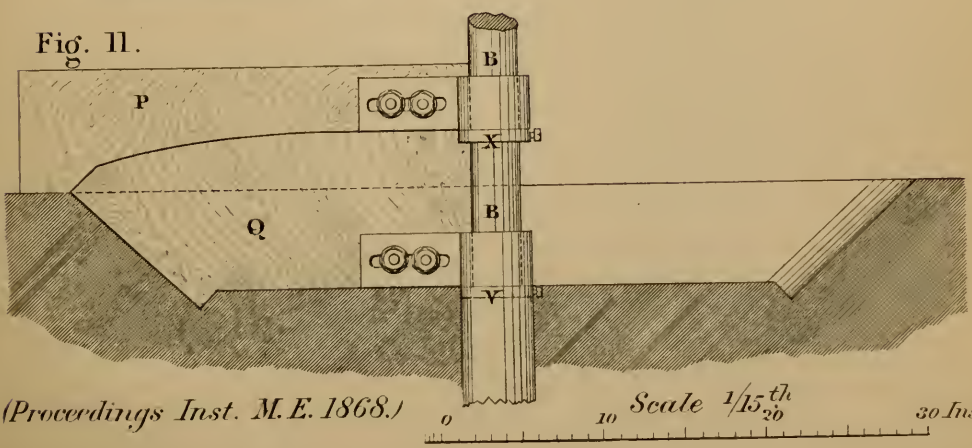


Fig. 11.



(Proceedings Inst. M.E. 1868.)

Scale $\frac{1}{15\frac{th}{20}}$

0 10 30 Ins.

PROCEEDINGS.

5 November, 1868.

The General Meeting of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Thursday, 5th November, 1868; Frederick J. Bramwell, Esq., Vice-President, in the Chair.

The Minutes of the last Meeting were read and confirmed.

The Chairman announced that the President, Vice-Presidents, and five Members of the Council in rotation, would go out of office in the ensuing year, according to the rules of the Institution; and that at the present meeting the Council and Officers were to be nominated for the election at the Anniversary Meeting.

The following Members were nominated by the meeting for the election at the Anniversary Meeting:—

PRESIDENT.

Sir William G. Armstrong, . .	Newcastle-on-Tyne.

VICE-PRESIDENTS.

(*Six of the number to be elected.*)

John Anderson, ...	Woolwich.
Frederick J. Bramwell, . .	London.
Edward A. Cowper, . . .	London.
Thomas Hawksley, . . .	London.
Sampson Lloyd, ...	Wednesbury.
W. Montgomerie Neilson, .	Glasgow.
John Ramsbottom, ...	Crewe.
C. William Siemens, . .	London.
Charles P. Stewart, . . .	Manchester.

COUNCIL.

(*Five of the number to be elected.*)

Alexander Allan,	Worcester.
Robert Broad,	Tipton.
John Fernie,	Leeds.
Sir Charles Fox,	London.
Edward Jones,	Birmingham.
William E. Marshall,	Leeds.
Walter May,	Birmingham.
John Robinson,	Manchester.
Francis W. Webb,	Bolton.
Percy G. B. Westmacott,	Newcastle-on-Tyne.
Richard Williams,	Wednesbury.

The Chairman announced that the Ballot Lists had been opened, and the following New Members were duly elected:—

MEMBERS.

William Coulson,	Durham.
Samuel Firth,	Leeds.
Henry Houldsworth Grierson,	Manchester.
John Heaton,	Nottingham.
William Shillito Hudswell,	Leeds.
George Frederick Lyndon,	Birmingham.
William Morris,	Chester-le-Street.
William Towndrow Stenson,	Coalville.

ASSOCIATE.

James Cordon,	Stoke-upon-Trent.

GRADUATES.

Frank Mappin,	Sheffield.
William Moor, Jun.,	Hetton.

A paper was then read "On the further utilisation of the Waste Gas from Blast Furnaces, and the Economy of Coke due to increased Capacity of Furnace," by Mr. Charles Cochrane, of Dudley; and the discussion was adjourned to the next meeting. (See Proceedings January 1869.)

The following paper was then read:—

ON AN IMPROVED FRICTION COUPLING AND BREAK, AND ITS APPLICATION TO HOISTS, WINDLASSES, AND SHAFTING, &c.

By Mr. THOMAS A. WESTON, of Birmingham.

The Frictional Apparatus forming the subject of the present paper has been successfully employed as a Clutch or Coupling and also as a Break. The applications already made are very varied, ranging upwards from the small friction bearings of toilet or swing glasses which yield a resistance of a few pounds only, to the "connector and break" of ships' windlasses for resisting a direct pull of thirty tons or more.

The apparatus consists of two series of friction discs, arranged alternately with each other upon a common axis, one series being carried by one shaft, and the other series connected to the other shaft or wheel which is required to be coupled with the first shaft. The discs on the first shaft cannot turn independently of it, but can slide lengthwise upon it towards or from each other: this series of discs are for convenience called the "shaft discs" in the following description. Arranged alternately with them are the discs of the other series, which have each a circular central opening sufficiently large to clear the shaft entirely; but at their outer edge they are slotted or made polygonal, or otherwise fitted in their outline to an external drum or cylinder containing them, so that they cannot rotate independently of the drum but may slide longitudinally within it. These discs are called for distinction the "intermediate discs;" and the drum containing them forms part of the spur wheel that is required to be connected to the shaft with a coupling or break

action; or the drum is attached to a second shaft lying in line with the first, with which the second shaft is required to be coupled. So long as no longitudinal compression is applied to the discs, the shaft discs with the shaft carrying them are free to rotate independently of the intermediate discs and the drum containing them; but upon compressing the discs together longitudinally into frictional contact, the rotary motion of one series is either transmitted wholly to the other series, or is controlled or arrested by friction against the discs of the other series; and the double series of discs acts thus either as a coupling or as a break. The great advantage arising from the alternate arrangement of the discs is that the frictional effect of any pressure applied to couple them is repeated as many times as there are discs in the two series; that is, the number of all the discs is a constant multiplier for the friction produced between a single pair of the rubbing surfaces by any given pressure.

This principle of the multiplication of frictional surfaces is illustrated by the diagram Fig. 1, Plate 105, where instead of two series of discs there are shown two series of short flat plates, arranged like the discs alternately with each other. The one series A A are severally tied to the fixed pillar C, and each one of the other series B B has its sides in frictional contact with two of the first series. The applied pressure for frictionally coupling the two series is furnished by the weight D. Upon withdrawing any one of the series B in the direction shown by the arrow, a certain degree of resistance will occur, in consequence of the friction upon its two sides due to the pressure of the weight D. Upon withdrawing two of the series B together, twice as much resistance occurs; and if the whole series B B are simultaneously withdrawn, the resistance is further increased in proportion to the whole number in that series. The double series A B represented in the diagram having eight pairs of rubbing surfaces repeats eight times over the friction due to the weight D acting direct upon one pair of surfaces; and in this case therefore eight is a constant multiplier for the friction due to any given pressure at D. Hence, as the number of the plates or discs may be indefinitely increased, an indefinite increase or extension

of frictional area may be obtained, without any reduction of the pressure per square inch upon the rubbing surfaces; in consequence of which the remarkable result is obtained of an indefinite increase in the total amount of friction with the same load.

It may be remarked as an illustration that this principle of the repetition of frictional surfaces is the basis of the structure of ordinary hempen ropes. In that case contiguous fibres present their surfaces to each other in frictional contact, and the frictional adhesion between them is due to the initial pressure given by the original twist in the strands, and to the resultant pressure arising from the oblique direction of the strain upon the fibres under a load; and a rope of an inch diameter is stronger than a half-inch rope because of the greater number of fibres in frictional union which it contains. The "coupling" pressure upon the fibres may be wholly removed by completely untwisting the strands of the rope; and the strength of the rope will then have disappeared, simultaneously with the loss of the frictional union of its fibres.

In Fig. 2, Plate 105, is represented a form of experimental friction break or coupling, composed of two series of circular friction discs A A and B B, the relative motion of the rubbing surfaces being circular, instead of in a straight line as in Fig. 1. The shaft discs A are made an easy fit upon the square shaft C, so that they may slide to or from each other upon the shaft into more or less intimate contact with the intermediate discs B; and the latter, when no coupling pressure is applied, are capable of turning freely upon the circular bosses of the shaft discs A. The coupling pressure is applied or withdrawn by means of the cranked lever D, the short forked arm of the lever compressing the discs longitudinally upon the shaft against the fixed pin E. So long as no compression is applied, the shaft C can rotate freely, carrying with it the discs A, which do not then transmit any driving force to the discs B; but upon compressing the discs into frictional contact with each other, the rotary motion of the shaft will be transmitted by the discs A to the intermediate discs B. The rotation of the shaft being maintained, and the discs B being held from turning by a cord F wound round

the circumference of each, the tension upon each cord measures the friction between each two pairs of the circular rubbing surfaces; and the strain upon all the cords taken together is the total force which the whole series of intermediate discs B is then absorbing by break action upon the shaft discs A. The collective strain upon all the cords represents also the tangential force which under the same pressure the discs B will transmit at their circumference when employed as a coupling, together with the difference between the friction of motion and the friction of repose; this strain is indicated by the spring balance H, upon which all the cords pull by the intervention of the crossbar G. The ratio of the strain on the spring balance H to the coupling pressure applied by the lever D is constant for all pressures; that is, in the same coupling and break, or in one containing the same number of friction discs, which have the same pitch line or centre of friction, and are made of similar materials with their rubbing surfaces in the same condition. To illustrate this uniformity of action, the coupling pressure at D may be applied gently and increased by imperceptible gradations to any required extent, and in like manner gradually withdrawn again; and the tangential force indicated by the spring balance H will simultaneously rise and fall with the same steady regularity. The coupling pressure may also be applied and withdrawn very suddenly, or even with a jerk, and proportionate extremes of force will then be indicated with the same abruptness by the spring balance H; and this will be the case, whether the fluctuations of the applied pressure are faint, arising from very minute but sudden variations like rapid pulsations, or whether the variations are excessive as well as rapid. This sensitiveness of the friction coupling is due to the parallelism of its rubbing surfaces, since the frictional action between parallel plane surfaces necessarily fluctuates in true and instant correspondence with every variation of the applied pressure.

The power of the coupling and break, which might be increased if necessary so as to exceed the ultimate strength of the shaft without any sacrifice of sensitiveness, is due to the principle of repeating the frictional surfaces, whereby the total area of frictional contact can be increased indefinitely without diffusing or diminishing

the initial pressure between the frictional surfaces; that is, every disc repeats without diminution the frictional effect produced by the applied pressure upon the first pair of surfaces. The arrangement of the double series of alternate discs possesses peculiar advantages in the varieties of adaptation of which it is susceptible, enabling it to be used under widely different conditions. Where the space available for a friction coupling or break is limited in a radial direction, so that the discs are required to be small in diameter, the necessary amount of friction is obtained by extending the coupling lengthwise along the shaft, employing an increased number of the discs to compensate for their small diameter. On the other hand, where the space is limited longitudinally upon the shaft, involving the use of fewer discs, their diameter can be increased to give the necessary amount of frictional surface.

The materials and structure of the discs may be very various. For the severest strains both series of discs are made of iron, one series being faced with wood segments placed endways of the grain. A coupling capable of very high duty, and one very compact in form, is obtained by employing thin sheet steel for the material of both series of discs, and facing one series with leather faces on both sides, the leather being attached by fine copper wire passed through small holes in the steel discs. For break purposes iron and wood discs are employed, and the wood discs are thoroughly saturated with linseed oil and the iron discs made smooth; the wear of the discs then becomes imperceptible. In consequence of the large amount of rubbing surface obtained, the lowest coefficient of friction suffices, and the break may therefore be always lubricated if desired, and is still sufficiently powerful. The pitch line or centre of friction of the discs is the circle dividing their working faces into two equal annular areas. By enlarging the central opening in the intermediate discs, so as to make their working face a narrow annular ring, the pitch line is thrown further outwards from the shaft, and the power of the coupling is thereby increased by increasing the leverage at which it acts; but for break purposes this reduction of the actual area is not always desirable, as it reduces the amount of wearing surface, though increasing the efficiency of the break.

For a coupling required to transmit motion and to cease doing so instantly at definite points in a revolution with exact precision, the intermediate discs are sprung apart by means of small springs placed near their edges, and the shaft discs are sprung apart by small spiral springs in their bosses, as shown in Fig. 2. This plan of springing the discs apart when the pressure is withdrawn renders the coupling applicable to vertical or inclined shafts, or to a shaft having other motions than simply round its own axis. By employing springs of graduated strength between the discs, a coupling or break may be arranged for obtaining a gradually increasing frictional action, by making only one pair of faces come into action first; and during the time that this one pair only is in contact the frictional action between them can be gradually augmented by a gently increasing pressure, until the springs separating the next pair of discs are sufficiently compressed to bring these also into action, and so on until any required number of discs are in action. When all the discs have thus been brought into action the frictional resistance of a break constructed upon this plan will still continue to increase under a further increase of pressure, until all relative motion between the two series of discs has ceased. This arrangement for bringing the discs successively into action will give a graduated effect uniformly increasing by delicate and scarcely perceptible grades up to the full power of the break; and it might be advantageously applied for such purposes as arresting rapid rotation in centrifugal drying machines.

The practical applications described in the present paper of this friction coupling and break are those only which have proved economical and preferable to other frictional appliances; but many other applications are now in progress. For the purpose of hoisting, nearly four hundred crabs, cranes, and hoists, constructed upon this principle, have now been put to work; and the results of their use during five years have proved quite satisfactory. A 5 ton crab on this construction at the Bardon Granite Quarries, Leicester, is now working as well as when first used about five years ago; and during that period it has had nearly constant work in lifting empty trucks.

As friction couplings upon fixed driving shafts a considerable number of these couplings are at work, applied to small shafts of less than 3 inches diameter; and sufficient advantage has been found after nearly three years' trial to lead to the further adoption of the plan for much larger shafts, to which the coupling is now being applied accordingly.

In Figs. 3 to 5, Plate 106, is shown a portion of a 6 ton Hoisting Crab. Fig. 3 is a longitudinal section, and Figs. 4 and 5 are transverse sections showing separately one of the wood discs and one of the iron discs. The shaft discs A, made of wrought iron, are here five in number, with a square hole in the centre of each, fitting upon the square portion C of the shaft, Fig. 5. The four intermediate discs B are of elm wood, and engage with the external drum D by the slots in their edges, into which fit the longitudinal ribs on the inner surface of the drum, Fig. 4. The drum D forms a portion of the pinion casting E, which when uncoupled turns freely upon the shaft; and for the purpose of hoisting it is coupled with the shaft by the frictional action of the discs A B in the same manner as in the preceding examples. The coupling pressure is applied by the handwheel F, the boss of which is screwed to traverse upon the screwed part of the shaft; and by this means the discs are compressed together against the collar G, upon which the pinion turns when uncoupled. The shaft carries at its ends the usual winch handles, and is also provided with the ordinary ratchet-wheel to prevent it turning backwards when the winch handles are released. For lowering the load it is only necessary to turn the handwheel F backwards, unscrewing it slightly from its pressure upon the discs, until the load makes the pinion E run backwards; and the speed of lowering is controlled with great exactness or the descent of the load can be instantly arrested without exertion by again screwing the handwheel forwards upon the break. The advantages obtained in this case are despatch and safety; the winch handles never turn backwards in lowering, and the load is kept completely under control with the greatest ease.

In Figs. 6 and 7, Plate 107, is shown a Sack Hoist, as used without tackle blocks; and with the blocks it forms a convenient

hoist for weights up to half a ton. Fig. 6 is an end elevation, and Fig. 7 a longitudinal section to a larger scale. The winding barrel D is loose upon the shaft, and is recessed at one end to form the break drum. The coupling and break is exactly similar to the one last described, the five iron shaft-discs fitting upon the square part of the shaft C, and the intermediate wood discs engaging with the ribs inside the drum D. The rope-wheel F is screwed to traverse upon a screwed portion of the shaft. A ratchet-wheel G fixed upon the shaft prevents it from turning backwards, and also forms a collar or abutment to receive the coupling pressure applied by the screwed boss of the rope-wheel. An endless rope passes over the rope-wheel, and on pulling the rope in the direction for hoisting, the rope-wheel advances upon the screw and compresses the friction discs, until the friction between them is sufficient to couple the winding barrel D to the shaft C. On continuing the hoisting motion the load is then raised, and is held suspended at any point by the ratchet-wheel G. For lowering the load it is only necessary to pull the rope in the opposite direction, and as the shaft cannot turn backwards on account of the ratchet-wheel, the rope-wheel is thereby withdrawn, relieving the friction discs from pressure; and the winding barrel being thus uncoupled from the shaft runs backwards on it with the load. The speed of lowering is under perfect control by holding the endless rope with one hand on each side, and applying the break as required to check the descent of the load, by pulling the rope slightly in the direction of hoisting, so as to screw the rope-wheel up against the friction discs. This arrangement of hoist has the advantage that both the hoisting and the lowering are done at pleasure by means of the single endless rope, which affords perfect control over the load at all times.

In Figs. 8 and 9, Plates 108 and 109, are shown portions of one of Messrs. Harfield's Ships' Windlasses for a 2 inch chain-cable, the frictional apparatus being employed as a "connector" or coupling, and also as a break. This application has been approved by the Admiralty, and the windlass has been introduced for use in the navy. Fig. 8 is a sectional plan and Fig. 9 a transverse section

of the windlass, taken through the break drum. The cable-holder or chain-wheel C is cast in one piece with the break drum D; and when the friction discs are uncoupled, the chain-wheel can turn freely on the horizontal shaft E, which is supported in the cast-iron framework F F of the windlass. The shaft E is rotated by the pair of nipping wheels H keyed upon it, one of which only is shown in the drawing, each wheel being fitted with a nipping lever G; the pair of nipping levers receive an alternate up and down motion from a reciprocating sway beam, at the opposite ends of which the two levers G are attached, the beam being worked up and down by manual labour. In the downward movement of the nipping lever it slips down freely over the rim of the wheel H until it jams itself; and then in the upward movement it bites or nips the wheel and turns it forwards through a portion of a revolution: in this way by the alternate action of the pair of nipping levers the shaft E is rotated with a continuous motion in the direction of the arrow in Fig. 9.

The boss of the nipping wheel H projects inwards within the break drum D, Fig. 8, to a sufficient distance to carry the required number of friction discs; and its exterior is shaped with three solid keys J J, Fig. 9, which engage in corresponding slots in the iron shaft-discs A. There are six of the shaft-discs, which are made of wrought iron galvanised for preventing corrosion. The seven intermediate discs B B are made of teak wood, and are of square outline with the corners bevilled off, engaging with the drum D by their angles, as shown in Fig. 9. The coupling pressure for compressing the friction discs together is applied by means of the screw N turning loose on the shaft E and working in the nut M, to which the back plate K at the further end of the series of friction discs is connected by the three longitudinal bolts L passing through holes in the boss of the nipping wheel H; by turning the screw forwards the back plate K is tightened up towards the nipping wheel H, compressing the discs with the required pressure. The screw N is made with a capstan head, having recesses O round its circumference to receive a hand lever for turning it, when a heavy pressure is required upon the friction discs for coupling the chain-

wheel C solidly to the nipping wheel H. For light pressures or for break action the screw is turned by the small handles P fixed round its circumference; and one quarter turn of the screw is sufficient to stop altogether the running out of the cable or to release it entirely.

One end only of the windlass is shown in the plan, Fig. 8, and the opposite end of the shaft E carries an exactly similar chain-wheel C and nipping wheel H; so that the continuous rotary motion given to the shaft E by the pair of nipping wheels H may be transmitted to either one of the chain-wheels C by applying the coupling pressure to the set of friction discs with which each chain-wheel is provided. As a connector this application of the friction discs offers the advantage of connecting the chain-wheel with the shaft of the windlass at any point in a revolution, without letting go of the cable or taking in any more of it; and as a break its power and compact form have proved very advantageous. A windlass of the size shown in Figs. 8 and 9 is suitable for a ship of 1800 tons register, the iron shaft-discs being 23 inches diameter and $\frac{1}{4}$ inch thick, and the intermediate teak discs 23 inches square and $\frac{3}{4}$ inch thick.

In an experiment with one of these windlasses of a smaller size, containing six pairs of the friction discs, upon which the coupling pressure was applied by a lever $3\frac{1}{2}$ feet long with the force of two men, the friction break served to hold and control a direct pull upon the cable of 34 tons, without injury to the friction discs. In this case the iron discs were $14\frac{1}{4}$ inches diameter and $\frac{3}{16}$ inch thick, as shown in Fig. 10, and the wood discs were $\frac{3}{4}$ inch thick with a centre hole 11 inches diameter, as shown in Fig. 11.

In Fig. 12, Plate 110, is shown a simple form of Shaft Coupling, employed to drive shaking or tumbling barrels at Messrs. Nettlefold's screw works, Birmingham. Fig. 12 is a longitudinal section, and Figs. 13 and 14 are transverse sections showing the iron and wood discs separately. The five iron discs A engage with solid keys on the long boss of the spur wheel E, within which the driving shaft C turns freely when no coupling pressure is applied to the discs. The drum D containing the six intermediate wood discs B slides on

feathers on the shaft C, and the groove G on the outer end of the drum receives the forked end of a lever by which the coupling pressure is applied, compressing the discs against the fixed collar F on the shaft, and thereby coupling the spur wheel E to the shaft C. To prevent wear, the forked end of the lever is faced with segmental pieces of hardened steel; and the loss of power by end pressure upon the shaft is not found to be any serious amount. The advantage realised by this arrangement of frictional shaft coupling is the prevention of breakage to gearing and straps, which was previously of very frequent occurrence.

In Figs. 15 and 16, Plate 111, is shown a Safety Clutch, intended simply for preventing breakage by overstrains; it was constructed for driving agricultural machinery by the power of oxen. Fig. 15 is a longitudinal section, and Fig. 16 an end elevation and transverse section. The clutch forms a frictional connection between the two shafts C and E placed in line with each other, the shaft C carrying the four iron discs A, which slide on keys upon it, while the other shaft E carries the drum D securely keyed to it. A cover plate, through which the shaft C passes freely, is secured to the drum D by the six bolts G G passing through near its outer edge; and these bolts form the ribs or projections inside the drum for engaging with the five intermediate wood discs B. The coupling pressure is applied by the four set-screws H H, which are adjusted by hand to the required pressure. By this means the power which the clutch will transmit without slipping can be adjusted with nicety, according to the work to be done or the strength of the machines to be driven; and any sudden increase of resistance or of driving power, beyond the limit to which the clutch is adjusted, will cause the friction discs to slip upon one another, whereby all liability of injury or breakage is prevented.

In Figs. 17 and 18, Plate 112, is shown a Self-Engaging Friction Coupling, applied to shafting at Messrs. Whitbread's brewery in London. The driving shaft C carries the four iron discs A, as before, and the drum D containing the five intermediate discs B of elm wood is keyed on the driven shaft E. The coupling pressure is applied by the spiral springs I I, inserted between the inner end

of the drum and an iron disc or cover plate K bearing against the first of the wood discs B. The plate K is connected by the bolts H with the exterior sliding collar G, which is grooved to receive the steel ring L carried by the forked end of the hand lever M; so that by means of this lever the coupling pressure can be taken off the friction discs at any time; and by locking the lever in this position with the pressure withdrawn, the coupling ceases to transmit the power from the driving shaft C, and the shaft E with the drum D accordingly remains at rest. On releasing the lever M, the coupling immediately throws itself into gear again, with a self-engaging action, by the springs I pressing the series of discs into frictional contact; and the two shafts are then coupled and revolve together, without any loss of power by end pressure.

In Fig. 19, Plate 113, is represented an application of the friction coupling as a Lathe Coupling, as applied by Messrs. Tangye of Birmingham to a three-spindle lathe. The drawing is a transverse vertical section through the lathe-bed and saddle. The friction coupling is applied to the back-traverse motion of the lathe, in place of the ordinary cone clutch so often employed in similar situations, which however is found not to transmit sufficient power nor in so convenient a manner for lathes of this description, where there are three cutting tools acting simultaneously. The back shaft K carries as usual a travelling wormwheel geared to the tangent wheel M, which is made with a projecting hollow boss L that contains the intermediate friction discs of elm wood. The iron shaft discs are carried on the hollow shaft N N, on which is also fixed the spur pinion O gearing with the ordinary traverse rack R by means of the spur wheels P P. Within the hollow shaft N is a rod T T, having at one end a large collar or plate to pull inwards against the friction discs; and on the other end of the rod T is a small cross lever S with screwed boss, by means of which the coupling pressure is applied upon the friction discs, when it is required to couple the tangent wheel M to the hollow shaft N.

In Figs. 20 and 21, Plate 114, is shown a form of Safety Pinion, intended to prevent the shaft to which it is applied from transmitting or receiving any excess of force beyond a fixed limit. The iron shaft

discs A A, shown in section in Fig. 20, are here bevilled in one direction, and the intermediate discs B B, which in this case are also of metal, are bevilled in the opposite direction. This sectional form gives great compactness, allowing nearly double the number of discs of any given strength to be placed within the same longitudinal space upon the shaft C. The discs are tightened up with the required amount of coupling pressure by means of the nut E. The intermediate discs B are made larger in diameter than the shaft discs A, to a sufficient extent to allow of the pinion teeth F F being formed in the projecting rims of the intermediate discs, as shown in Fig. 21.

In Figs. 22 and 23, Plate 115, is shown a Sack Hoist, intended for small weights up to 5 cwts., and possessing the valuable property of being self-sustaining, so that the load can in no case run down of itself, but requires to be lowered continuously by the hand rope. The rope-wheel F and the winding barrel D are both loose upon the main shaft C, between the small fixed collar E and the large disc H cottered on the shaft; a ratchet-wheel G, Fig. 23, keyed on the shaft between the collar E and the rope-wheel, prevents the shaft from turning backwards. The boss of the rope-wheel F has its outer face made plain and smooth for frictional contact with the adjacent side of the ratchet-wheel G; and the flange K at the other end of the winding barrel D is in like manner faced to rub against the disc H. The side of the rope-wheel boss F that is adjacent to the winding barrel is formed with a spiral inclined face I or single convolution of a screw, which engages with a similar spiral incline J formed upon the end of the winding barrel D. The diameter of the other side of the rope-wheel boss which rubs against the ratchet-wheel G is made rather greater than the diameter of the screw inclines I and J; and the pair of rubbing faces formed by the flange K and the disc H are made as large as convenient, for the purpose of gaining break power in lowering.

The action of this construction of hoist is as follows. On turning the rope-wheel forwards, in the direction for raising the load, the inclined surface of the spiral between the rope-wheel and winding

barrel tends to separate them endways, and thus produces an end pressure, which tightens together the external plain rubbing surfaces with a pressure proportionate to the load sustained by the winding barrel. The rope-wheel and winding barrel are thus jammed between the fixed collars E and H on the shaft, and the several parts of the hoist are thus firmly coupled together, so that the continued forward rotation of the rope-wheel F carries with it both the winding barrel D and the shaft C, thereby raising the load and turning the ratchet-wheel G forwards. For lowering the load, the rope-wheel being turned backwards by hand withdraws one incline from the other in the spiral clutch, and thereby relieves the friction surfaces from the end pressure, so that the winding barrel is released and the load can descend; but the descent of the load can only take place so long as this withdrawal of the inclines is continued by the rope-wheel continuing to be turned backwards by hand, allowing the winding barrel to follow. The moment the rope-wheel is stopped, the inclines become tightened again upon each other by the load acting on the winding barrel; the rope-wheel and winding barrel are thus again jammed endways between the friction surfaces of the ratchet-wheel G and disc H, which being held by the ratchet from turning backwards prevent the load from running down further. This arrangement accordingly provides the means of lowering as well as raising the load continuously and steadily and with perfect safety, avoiding the risk of injurious jerks on the chain; while at the same time the load is securely held suspended at any point at which the rope-wheel may be stopped.

In the construction of this hoist, the diameter and angle of the spiral inclines, and the diameter of the frictional surface presented by the ratchet-wheel, are so proportioned as not only to make the load self-sustaining at any point at which the hoisting force ceases, but also to render the lowering motion self-arresting; so that the descent of the load ceases as soon as the backward turning of the rope-wheel by hand is discontinued, and the winding barrel in running backwards under the influence of the load is not able to drive the rope-wheel before it by means of the inclines, however

great may be the load suspended from the winding barrel. In the sack hoist shown in Fig. 22 this result is attained by making the diameter of the frictional surface of the ratchet-wheel a little greater than the diameter of the spiral inclines, the friction surfaces in this case being iron upon iron, and the pitch of the spiral being $\frac{1}{2}$ inch in a diameter of 4 inches, giving an angle of about 1 in 24 for the inclines. This very fine pitch is intended for light weights only, and for heavier loads a coarser pitch would be employed with a proportionately larger diameter for the friction surface of the ratchet-wheel. When the proportions of these parts have been suitably adjusted for sustaining any given load, the self-sustaining and self-arresting property of the hoist is not affected by any increase or diminution in the load, because any change in the load is attended with a proportionate change in the amount of end pressure produced by the inclines and in the consequent frictional resistance offered by the rubbing surface of the ratchet-wheel. Under any load whatever therefore the frictional resistance or adhesion between the rubbing surfaces of the ratchet-wheel and the rope-wheel boss, arising from the oblique action of the inclines, is always greater than the direct rotary driving force of the winding barrel upon the rope-wheel through the inclined faces of the spiral clutch. With the proportions above mentioned, the sustaining friction is so little in excess of the load that only a slight amount of force is sufficient to turn the rope-wheel backwards for lowering the load; and the rope-wheel being made heavy, to act as a flywheel, a tolerably vigorous pull upon the rope causes the wheel to make a number of revolutions backwards, allowing the winding barrel to follow and lower the load with proportionate rapidity; but as the frictional resistance slightly preponderates, the lowering takes place with perfect safety, and the load gradually ceases to descend as the rope-wheel loses its momentum. The lowering of the load therefore continues only so long as the backward motion of the rope-wheel is continued by hand, and the descending load comes to rest at any moment that the rope-wheel ceases to be turned backwards. The one endless rope thus affords the means of both raising and lowering weights continuously and steadily, by simply working the rope-wheel by hand in opposite

directions; and at the same time all possibility of accident from the load running down of itself is avoided.

The frictional faces by which the load on the hoist is sustained are iron upon iron, where lubrication can be depended upon; but in other cases one wood face is introduced. This construction of hoist is also capable of very advantageous combination with the friction disc coupling and break previously described, where a large amount of break power is required; but for a variety of purposes the use of the spiral inclines renders the addition of the friction discs unnecessary.

In Figs. 24 and 25, Plate 116, is shown a Bracket-Winch or Side-Winch, constructed upon the same self-sustaining principle as the sack hoist last described, the lowering being done continuously by turning the handle of the winch backwards, so that the load is lowered slowly and cannot run down of itself. One of the spiral inclines or screw faces is here formed upon a collar I, fixed upon the shaft C of the winch, which is turned by the handle F; and the other corresponding incline J is formed upon the end of the winding barrel D, which is loose upon the shaft. The flange K at the other end of the winding barrel is faced to rub against the ratchet-wheel G, which runs loose upon the boss of the flanged collar E cottered on the shaft C, the ratchet-wheel being situated between the flange E of the collar and the flange K of the winding barrel. The shaft C and winding barrel D are carried in a trough-shaped casting or bracket L L; and a recess in the framing of the bracket contains the paul H, Fig. 24, of the ratchet-wheel G. The action of this winch is exactly similar to that of the hoist last described, the spiral inclines having the effect of jamming the winding barrel endways against the ratchet-wheel and the fixed collar E; and the frictional surfaces sustaining the load in this case are the two sides of the ratchet-wheel G, which are in contact respectively with the flange of the collar E and the flange K of the winding barrel.

In Figs. 26 and 28, Plate 117, is shown a portion of a self-sustaining Hoisting Crab, in which the application of the spiral inclines as already described is combined with the friction discs of the couplings and breaks previously described, the lowering of the

load being performed slowly by continuously turning the handles of the crab backwards, in the same manner as last explained. The pinion D runs loose upon the shaft C of the crab, and is cast with a long boss of square exterior, which carries the two iron shaft-discs A A. The ratchet-wheel E, also turning loose upon the shaft C against a fixed collar, is cast in one piece with the break drum F, shown in section in Fig. 28, which contains the three intermediate wood discs B B. The collar G fixed upon the shaft has its end next to the pinion D formed into a spiral incline or screw face, which engages with the corresponding incline H formed upon the pinion D. The shaft C is rotated by the usual winch handles, and on turning it in the direction for hoisting, the inclines G and H ascending each other slightly produce a longitudinal pressure upon the friction discs A and B, thereby coupling the pinion D to the ratchet-wheel E, and both of them to the shaft C; the load is then raised by continuing to turn the shaft forwards, and is sustained at any point by the paul of the ratchet-wheel E. The lowering is done, as before, by turning the winch handles backwards, thereby relieving the friction discs from the pressure of the inclines; and the lowering takes place only so long as the winch handles continue to be turned backwards, and ceases as soon as they stop. The friction discs employed in this case serve to increase the area of the frictional rubbing surfaces and thereby diminish the wear upon them; they also afford the required amount of frictional connection with much less end thrust from the inclines, so that the longitudinal strain upon the shaft and collars is thereby reduced. The angle of the inclines may therefore be increased, and in the present instance it is made about 1 in 12, or a pitch of $\frac{5}{8}$ inch in a diameter of $2\frac{1}{2}$ inches.

In Figs. 27 and 28, Plate 117, is shown another arrangement of Hoisting Crab, in which the combination of the spiral inclines with the friction discs is applied in a different manner, and with a different result, allowing the load to be lowered quickly. The pinion P as before is loose upon the crab shaft I and its square boss carries the two iron shaft-discs A, the three intermediate wood discs B being contained in the drum O cast in one piece with the ratchet-wheel N, which is also loose upon the shaft I. The fixed

collar L however, on which is formed one of the spiral inclines, engages with the other incline M formed in the present arrangement upon the ratchet-wheel N, instead of upon the pinion P as in the preceding case. In hoisting, the effect of the inclines is the same as previously described, jamming the ratchet-wheel N and pinion P against the fixed plain collar K upon the shaft, and putting an end pressure upon the friction discs A and B, sufficient to couple the pinion to the ratchet-wheel, and both of them to the crab shaft I. But in lowering, the result of the difference in the present arrangement is that it is only necessary to turn the winch handles very slightly backwards in order to relieve the friction discs entirely from the coupling pressure; the pinion P is thereby liberated altogether from the friction by which alone it was held, and the load is then free to run down of itself. This arises from the circumstance that, as the incline M is here formed upon the ratchet-wheel N, which is held by the paul from turning backwards, it is prevented from following the other incline L when the latter is withdrawn by turning the crab shaft backwards; a slight backward turn of the winch handles is consequently sufficient to remove the end thrust or jamming action of the inclines, thereby annihilating altogether the frictional resistance by which the load was sustained. The descent of the load can be checked or stopped altogether at any moment with break action by turning the winch handles forwards again in the direction for hoisting, so as to restore the coupling pressure upon the friction discs by the action of the inclines; and the winch handles thus form a ready means of applying or withdrawing the pressure upon the friction break. The load is therefore under perfect control at all times without danger to the men working the crab; and great despatch is obtained by making the winch handles serve the double purpose of hoisting the load and applying the break in its descent.

The preceding arrangement of crab, shown in Fig. 26, gives a very safe lowering motion, but only as quick a one as can be conveniently imparted by the continued backward rotation of the winch handles. The present arrangement, shown in Fig. 27, allows the load to run down freely of itself, but the rapidity of its descent

is checked and controlled at pleasure by the application of the friction break by means of the winch handles. The absolute safety attending the self-sustaining slow-lowering crab is therefore wanting in the present quick-lowering crab; or rather the safety is here dependent upon the care exercised in applying the break.

The rather slow but unquestionably safe lowering motion obtained by the arrangement shown in Figs. 22 to 26 is considered by the writer to be of especial value for jib cranes and other hoisting apparatus, where it is necessary to guard against the framework or foundations being exposed to any injury from suddenly checking by break action a load descending at an excessive speed. This arrangement would also be useful and safe as a means of varying the angle of inclination given to the jib of derrick cranes, and retaining the jib securely in any desired position without risk of slipping. In like manner it could be applied to wind in or let out the guys or stays of sheer legs and other hoists of similar structure; and generally for any purpose where a very safe backward motion is required for any pinion or drum upon its shaft, this hold-fast or self-sustaining arrangement would be valuable. The combination of the spiral inclines with the friction discs, in the manner shown in Fig. 26, furnishes a powerful and continuously self-acting break; that is, as fast as the coupling pressure is withdrawn, permitting the load to descend, it is continuously restored again by the load itself, so that the load is thus entirely incapable of running away; and as the power of the discs for break action may be increased to almost any degree, any load, however great, may be lowered in this manner with absolute safety.

Mr. Weston exhibited a number of working models and specimens of the various applications of the friction coupling and break, and showed the raising and lowering of weights by the two constructions of sack hoist described in the paper, the first plan allowing the load

to run down freely when released by the handwheel rope, which also served as a break to check the descent at any moment, while the second plan required the handwheel to be continuously turned backwards during the whole time of lowering.

Mr. E. A. Cowper thought the new arrangement of friction break or clutch was very good and would be available for many purposes. One of the most valuable applications of the plan appeared to him to be the frictional spur gearing shown in Figs. 20 and 21, where the safety pinion was composed of a series of pinions or toothed discs loose upon the shaft, alternating with plain discs fitted to the shaft, and by compressing the whole together endways each pinion was pinched equally between the shaft discs, so that each would do exactly the same amount of work, and the driving power transmitted by the whole pinion would be equally distributed across the entire breadth of the teeth of the spur wheel geared with the pinion. The two different modes of lowering the load in the two frictional crabs were also very good, the same principle of the inclined plane being employed in each case, either for relieving at once the whole end pressure on the friction discs, or for easing it off gradually by turning the winch handle backwards continuously. The latter plan had the advantage of being very safe and avoiding jerks, as the load could not run down of itself; and the former gave great facility for lowering very quickly in cases where there was not any danger from rapid lowering, as in the instance of lowering empty barrows &c. in connection with builders' scaffoldings. The thickness of the alternate iron and wood discs employed in the various couplings and breaks was certainly very small, the iron discs being only $\frac{1}{4}$ inch thick and the wood $\frac{3}{4}$ inch thick; and he enquired in reference to the wear and tear upon them, whether the wood discs being so thin had been found to give way in any case at the circumference under the strain to which they were subjected.

Mr. Weston replied that in the early form of the windlass break the plan of holding the wood discs by means of notches fitting upon projecting ribs in the interior of the drum containing the discs, as shown in Fig. 4, was found insufficient, and the wood was liable to break away from the projections when subjected to a heavy strain;

and the square form for the outside of the wood discs was then resorted to, as shown in Fig. 11, with the corners of the square discs bevilled off, which was found to get over the difficulty completely, and had never failed. For cranes and crabs however the first form of discs answered well.

Mr. E. A. Cowper observed that the use of an iron disc interposed between two iron discs lined with wood, for the purpose of forming a friction clutch, had been adopted by Mr. Ramsbottom in the reversing rolling mill at Crewe, for connecting the engine shaft to the rolls (see Proceedings Inst. M.E. 1866 page 116); in that case however the two wood surfaces were nipped between the iron discs by bolts all round the circumference, each tightened up separately, so that the pressure could only be adjusted approximately in the first instance, and there was no means of altering it quickly for variations in the amount of driving power to be transmitted. The employment of a number of friction discs, as in the new arrangements now described, had the advantage that much less pressure upon the discs was required for transmitting the same amount of power; and by employing a sufficient number of discs in the coupling it might even be possible to throw a heavy mill in and out of gear, or to reverse it, by means of a friction coupling, with the power of only one man acting on a hand lever. He thought the several applications which had been described only required to be more known in order to be more generally used. One point that occurred to him was, that in the use of the incline or spiral clutch for putting the end pressure upon the frictional surfaces in the hoists described in the paper, if the inclination of the spiral were supposed to be 12 to 1, the end pressure produced by it would be twelve times as great as the load on the chain barrel, and consequently there would be a shearing strain of that amount upon the pin holding the fixed collar on the shaft.

Mr. Weston replied that it was so, but as the loads lifted by that construction of hoist were not great, the end pressure upon the collar was not material; and it could be reduced to any required extent by the introduction of friction discs in combination with the inclines, as shown in the crabs.

The CHAIRMAN enquired whether any data could be furnished in reference to the amount of power that could be safely transmitted with a given extent of frictional surface, so as to allow of some idea being formed as to the number and size of discs required for a clutch to drive a rolling mill for instance; as the applications to shafting described in the paper did not appear to extend to the case of very large shafts.

Mr. WESTON replied that the nearest approach to the case of a clutch for driving rolls in ironworks was the windlass break for ships, shown in Figs. 8 and 9, in which it was found that six pairs of the discs of a smaller size than there represented were amply sufficient to hold against a pull of 34 tons on a ship's cable. In that case the iron discs were $14\frac{1}{4}$ inches diameter, and the central hole in the wood discs was 11 inches diameter, the material of the discs being wrought iron and teak alternately; the end pressure upon the discs for sustaining the strain of 34 tons was applied by means of two men acting on the break screw (N, Fig. 8) by a hand lever 3 feet long.

Mr. W. F. BATHO said he had introduced the friction coupling for driving the shafting and machinery at Messrs. Nettlefold's screw works which had been referred to in the paper, and it had been found of very great advantage there, and was now used in all cases where previously the ordinary clutches had been employed. It was a very ingenious application of a simple principle, which he thought was capable of very extensive adaptations. With regard to the wear of the wood discs, he had found this to be very slight, scarcely indeed amounting to anything appreciable; and the only way in which he could imagine that the coupling could be injured by a strain put upon it would be by the end pressure on the discs being very suddenly applied under a heavy strain, in which case the strain would be thrown upon the iron discs more in the manner of a blow, and might possibly occasion wear of the keys connecting the iron discs to the shaft, and so cause the discs to get loose and break the keys. He had not had any experience however of strains sufficiently heavy to produce such a result in any of the couplings that he had adopted.

Mr. WESTON remarked that in the couplings intended for heavy strains the size of the main shaft gave the three keys holding the iron

discs sufficient leverage to withstand any concussive action arising from throwing the strain suddenly upon the coupling. This was satisfactorily proved by the results of working of the windlass break for ships' cables, which had been approved and adopted by the Admiralty; and the plan had also been used by Messrs. Harfield of London for driving ships' capstans by steam power. The durability of the wood discs in the couplings and breaks was sufficiently established by Mr. Penn's experiments on wood bearings, which had satisfactorily proved that under a pressure of even 1200 lbs. per square inch on lignum vitæ running on iron no perceptible wear took place during long continued working (see Proceedings Inst. M. E. 1856 page 27). In the present case the wood used for the discs in the ships' windlass was teak, which of course would not be so durable as a harder wood; but at the same time the pressure per square inch upon the friction discs was far less than in the above experiments. Elm was employed for the discs of the cranes and smaller hoists.

Mr. C. W. Siemens observed that in the experiments on wood bearings the rubbing surfaces were immersed in water, and he enquired whether the wood discs in the friction break were lubricated with oil or water.

Mr. Weston replied that the wood discs were saturated with linseed oil before being put in their places, and when so treated he had not found they required any further attention or lubrication subsequently under any pressure that they were subjected to.

Mr. E. H. Carbutt mentioned that a useful application of the wood friction discs on a small scale had been made to the bearings of looking-glasses, so as to hold the glass firmly in any position into which it might be turned; he had seen one of these small bearings very severely tested by being put in a lathe and run continuously for a week under pressure without lubrication, and no perceptible wear of the wood had been produced.

The Chairman observed that the double amount of friction arising from the two sides of a plate or disc being both in frictional contact had hitherto been recognised in general only as a difficulty to be overcome in connection with machinery; as in the case of a steam

engine having two slide-valves, one on the back of the other, where the extra friction on the lower slide due to the double surface not infrequently occasioned breakage of its valve rod. This principle however of the friction increasing with the number of surfaces in contact, which had previously been only a source of trouble, had now been taken advantage of in a very ingenious manner in the construction of the friction coupling and break described in the paper. He had had the opportunity of seeing the shaft couplings on this plan at Messrs. Nettlefold's works, and considered that nothing could possibly work better than that arrangement; and he was therefore fully prepared to hear that it had been found entirely satisfactory in continued working, as had now been stated.

He proposed a vote of thanks to Mr. Weston for his paper, which was passed.

The following paper was then read :—

ON THE MOULDING OF TOOTHED WHEELS, AND AN IMPROVED WHEEL-MOULDING MACHINE.

By Mr. GEORGE L. SCOTT, of Manchester.

The apparatus for Moulding Toothed Wheels to be described in the present paper has been designed by the writer to supply the means of obtaining strictly accurate castings by machine moulding, with a portable and self-contained machine of small cost, capable of being readily and quickly applied at any part of a foundry.

The accuracy and perfection of the teeth of wheels are of great practical importance in all cases of gearing, and especially where large amounts of power are transmitted by them; and it is requisite that the transmission of power should be uniform and continuous through the teeth of the wheels, corresponding to the continued frictional contact of two circles rolling upon each other. To maintain this uniform and continuous action in toothed wheels, all the teeth throughout the circumference of the wheel are required to be precise duplicates of one another in form, size, and spacing; and all to be placed in a perfect circle round the centre of the wheel. Should these conditions be imperfectly carried out, the essential continuous contact will be destroyed, and a serious intermittent knocking between the teeth will be caused, leading to the fracture of the wheel, and risking a stoppage of the machinery. Any defective fitting of toothed wheels also involves a waste of driving power from the irregular shocks in transmitting the power; and as a consequence the wheel will not last so long in such a case, owing to the friction causing extra wear of the teeth.

In the earliest method of making toothed wheels, the teeth were chipped out by hand from the solid edge of the wheel, upon which they were set out and shaped to template. Subsequently the teeth were formed on a wood model of the wheel, and moulded from this

model according to the plan in general use, involving the necessity of having a separate expensive pattern for each wheel that differs in form and pitch of teeth as well as in diameter. The result has been a vast collection of toothed wheel patterns to meet the requirements of ordinary trade demands; and this stock has become so costly in the expense of construction and of the storage space occupied, that it has led to an objectionable limitation in the range of pitch of wheels, in order to reduce the extent of the stock of patterns. The use of wood patterns for entire wheels involves further the practical objection of liability to distortion, both in the general contour of the wheel and in each tooth, owing to the irregular effects of expansion and contraction in the component parts of the pattern; as well as the unavoidable risk of variation in the forms and dimensions of the several teeth, in consequence of the different finish that each receives. The uncertainty too attending the drawing of an unwieldy pattern from its mould, and the distortion of the pattern that occurs from its lying in damp sand for a considerable time, are additional obstacles to the manufacture of a toothed wheel from the ordinary wood models with the correctness that is desirable.

The only method of overcoming these difficulties is by employing only a small segment as the pattern, and moulding the entire toothed circumference by repetition of this small portion: employing mechanical means for lowering and raising it, and for spacing out the teeth round the circumference of the wheel, so as to obtain the same certainty of accuracy throughout as is shown by a wheel divided and cut in a machine. This process was introduced by Mr. P. R. Jackson, and carried out with the greatest accuracy; and until the advent of his most valuable machine it may be said that no really correct toothed wheels were cast.

The object of the Wheel Moulding Machine forming the subject of the present paper is to extend the application of this process by the use of a portable machine, of small size and cost, that can be easily applied for moulding a toothed wheel in any part of a foundry. Having moulded one wheel, the machine can be fixed at another place for use, or be put away until required again, in the meantime

leaving the foundry floor clear and in the usual condition for ordinary work. It will enable any foundry to supply with rapidity and economy of manufacture wheels possessing the absolute accuracy which results from the use of a machine.

The machine is made of two sizes, one for moulding wheels from 12 inches to 5 feet diameter, and a larger size for wheels from 20 inches to 12 feet diameter. The smaller machine is shown in Plates 118, 119, and 120; and one of the machines is exhibited to the meeting. Fig. 1 shows an end elevation of the machine, Fig. 4 a side elevation, and Fig. 5 a plan.

A pedestal A, shown separately in Fig. 2, supports a centre pin B, which has a collar to bear upon the pedestal, and is provided with a projection that fits into a recess in the top of pedestal, whereby it is prevented from turning in its socket. The spindle C is bored to fit on the centre pin B, and is turned to pass up through the rest of the apparatus, which it supports, as shown in section in Fig. 6, Plate 120. Set-screws placed in the spindle C are used to fix it firmly on the centre pin B, and this being secured in the pedestal a continuous vertical centre spindle is thus obtained. Loose collars provided with set-screws and bored to fit the centre pin B are used for the purpose of elevating the apparatus above the pedestal A, in order the more readily to adapt it for moulding different breadths of wheels. One of these collars is shown at V in Fig. 11, and they are of 1, 2, and 3 inches in thickness respectively.

On the spindle C is carried the head D, shown in section in Figs. 6 and 7, and in this head slide the radial arms E E, connected together at their front ends by the transverse piece F, which forms the bed for the vertical sliding ram G. The arms E E are secured to the head D in any required position by four square-headed bolts passing through slots in the arms and through ears cast on the head; these bolts being screwed up bind the arms and head firmly together. The spindle C being firmly secured in the pedestal forms a stationary centre pillar for the machine, on which the head D is free to turn; and on the top of the spindle is keyed the wormwheel H, from which a connection is made to the arms E by the dividing apparatus shown in Figs. 1, 4, and 5. This consists of a worm I

gearing into the wheel H, and the change wheels J J J, the uppermost wheel being on the worm shaft and the lowest one keyed on the shaft K, which is carried by brackets on the arm E, and is provided with a loose collar acting as a bearing, so that the shaft may be withdrawn for altering the change wheels when required. The swing frame L carrying the change wheels is sufficient for two intermediate change wheels if required. On the shaft K is fastened a spring handle M, which fits a slot in a disc that is divided to guide the workman in the number of turns to be given to the shaft. The traversing screw O is carried by brackets on the arm E, and passes through the nut N bolted to the head D, so that by turning the screw O by the handwheel at the end the arms are moved in or out, to suit the varying diameters of wheels to be moulded.

On the slide bed F fits the vertical sliding ram G, which is held in by the cover R, shown in section in Fig. 8; and a hand screw S retains the ram in any required position. The bottom of the ram is bored to receive the angle bracket T, which is secured in it by steady pins; and to this is attached the segment pattern U of the wheel teeth to be moulded. The ram is moved up or down by a handwheel Y, having a worm gearing into a wormwheel, on the shaft of which is a pulley Z; from this pulley two chains pass in opposite directions, the one being secured to the bottom of the ram and the other to the top, and kept always tight by means of two lock nuts. An adjustable brass collar W is fitted on the ram, for indicating to the moulder when the ram is sufficiently lowered. An eye-bolt is fixed on the top of the centre pillar C of the machine, for attaching the foundry crane in order to remove the machine.

The process of moulding a wheel with this machine is as follows. A core box for the arms of the wheel is first prepared, and also two radial boards for strickling the form of the top and bottom of the wheel in the sand, which are shaped to the profiles of the face and back of the wheel. The top board P, shown in Fig. 11, has on its lower edge the profile of the back of the wheel; and the bottom board Q has also on its upper edge the counterpart profile of the back of the wheel, and on its lower edge the profile of the face. A pattern is

also made of a segment of the toothed rim of the wheel, consisting of two teeth only, which permits of moulding one space at a time.

A secure and steady foundation for the moulding machine is obtained by sinking in the sand of the foundry floor in the desired situation the pedestal of the machine, which is bolted to a cast-iron base-plate about 4 feet square; sand is then rammed solidly upon it, and the pedestal levelled so as to be truly vertical. Another form of pedestal is shown in Fig. 3, which is used for fixing in the sand without a base-plate. The top of the pedestal is placed about 15 inches below the floor level, this distance determining the greatest breadth of wheel that can be moulded. The centre pin B of the machine is then placed in the socket of the pedestal, for the purpose of forming the mould for the bed of the wheel, and also to mould the top box or other arrangement used to cover the mould for casting: the rest of the machine being laid aside for the present.

In Fig. 11 is shown the loose collar V which is placed upon the centre pin B, of such thickness that its upper face is the same depth below the floor level as the breadth of the rim of the wheel to be moulded; so that the back of the wheel is level with the floor, for convenience of fitting the top box on. This lower collar V is fixed by a set-screw, and an upper loose collar X is also fitted on the centre pin B by a set-screw, with its upper face at the same height above the collar V as the breadth of the rim of the wheel; the lower collar thus exactly indicates the level of the bed and face of the wheel, and the upper collar that of the back of the wheel. The hole is then filled up with sand to the level of the upper collar; and the iron trammel carrying the top board P is placed upon the spindle B, and worked round upon the collar X, forming a mould of the back of the wheel, which is then sprinkled with parting sand to form the parting for the top box. An ordinary top box or other sufficient covering is then placed on, and rammed up with sand; and the box is then staked in the ordinary manner, for the purpose of marking its correct position relatively to the bottom part of the wheel, by stakes driven into the sand and fitting by the side of corresponding ears upon the top box. The top box is then lifted off, carrying with it the impression of the back of the wheel; which impression is finished by

turning the box over, and strickling it again with the second trammel that carries the bottom board Q. A centre is provided in the top box for this trammel, by means of a loose collar, in which are two bolts that pass through the top box and are fastened across the bars of the box. This loose collar fits the spindle B, and is drawn from it with the top box, thus fixing a strictly accurate centre. By this arrangement the centering collar can be readily fixed upon any ordinary top box, giving strict accuracy in the moulding, without requiring any special boxes for the purpose.

For forming the bed of the mould the top collar X is then removed, and the mould being dug out to the level of the bottom collar V, the sand is strickled with the bottom radial board Q, worked round upon the bottom collar V. This forms the mould for the lower and outer faces of the teeth, and finishes the mould ready to receive the teeth and the cores for the arms; and as both the back and the face of the wheel have been struck from the same trammel and the same centre, perfect accuracy is ensured in the wheel.

The segmental pattern of the teeth U, Figs. 9 and 10, is then fitted truly square and central and secured by screws upon the angle bracket T of the vertical sliding ram G, Fig. 4. The upper portion of the machine is then placed upon the spindle B, the trammel having been removed; and the fixing screws in the spindle are screwed up, to maintain the central axis continuous through the machine. The segmental pattern U is adjusted by the traversing screw O, Fig. 5, to the correct radius of the wheel, measuring from the top of the tooth to the centre of the machine. The ram G is then lowered to the level of the bed of the wheel, and secured at that point by the locking screw S; and the brass collar W is adjusted on the ram and fixed by a set-screw, to ensure the ram always stopping at the same level, when lowered for moulding each successive tooth. The locking screw S prevents the ram rising from the pressure of ramming the sand. One space of the wheel teeth is then moulded by ramming sand in the space left between the pattern and the edge of the mould previously formed by the strickle board. The locking screw S being then released, the

ram carrying the pattern is raised clear of the mould, and is then traversed round through the exact distance of the pitch of the wheel, by means of the dividing handle and the change wheels previously arranged for the required pitch. The segmental pattern is then again lowered, and a second space moulded as before.

When all the teeth have been moulded, the fixing screws of the centre spindle are released, and the whole machine is then lifted away by the foundry crane laying hold of the eye-bolt on the top of the spindle, leaving the mould entirely clear to receive the cores for the arms and boss. The hole in the top of the pedestal is fitted with a cover to keep out the sand, and is then covered over with sand, which protects the pedestal against the action of the hot metal. The centre core for the wheel is adjusted as usual from the circumference, and the cores for the arms are set to their places by means of wood gauges showing the thickness of the arms and rim. The top box is then put on, to cover the mould, being placed in its correct position by the stakes previously mentioned; the runner is then formed, the box duly weighted, and the whole is ready for casting.

This mode of moulding wheels gives the certainty of strict accuracy and excellent finish throughout. The trammel revolving on a secure centre ensures a true circle in the circumference of the teeth; the dividing arrangement ensures the correct relative position of all the teeth; the mode of raising the tooth pattern ensures a gradual steady withdrawal from the sand, whereby the mould is left perfectly finished; the tooth pattern, having but one space from which the whole number of teeth are moulded in succession, produces each tooth an exact duplicate of all the others; and the arrangement for forming the mould and the top box from the same centre produces so good a joint that the occurrence of any fin on the edge of the teeth is prevented. This great superiority in the finish of the wheels moulded by the machine, as compared with hand-moulding from wheel patterns, is accompanied by a very important economy, saving the heavy outlay required for a large stock of costly wheel patterns; thus in the case of a wheel of 6 feet diameter and 12 inches breadth, instead of a complete wheel pattern costing about £10, the whole expense required with the machine,

for the tooth segment, core box, and strickling boards, will be only about 15*s*.

The moulding machine now described has the advantages of great compactness and convenience for use, as it occupies but little room; and being used in the foundry floor it effects a great saving in the expensive item of boxes. A special feature of advantage is the portability of the machine, which is a point of great importance; and as a consequence one machine is made to do the work of several, by simply fixing two, three, or more pedestals in different parts of the foundry floor, upon any one of which the machine can be quickly and readily placed for moulding a wheel: whilst those pedestals that are not required at the time are simply covered with sand, leaving the floor in its usual state, clear for other work. By this means the moulding of more than one wheel may be in progress at the same time, with the cost of only one machine in the foundry.

An important practical advantage obtained by machine moulding is the power of manufacturing wheels with an unlimited variety of dimensions, pitch, and forms of teeth, so as to meet exactly the requirements of any case that may occur: thereby avoiding the serious obstacles so frequently experienced of having to modify the intended wheel, in order to suit some existing range of patterns and obviate the serious cost and the delay attending the preparation of a new complete pattern.

As an example of the rapidity of moulding large wheels by means of this machine, it may be mentioned that a bevil wheel of 9 feet diameter and 12 inches breadth, weighing 3 tons, was moulded and cast within four days from the time of the order being given at the North Moor Foundry, Oldham; and in another case at Messrs. Buckley and Taylor's, Oldham, a shrouded bevil wheel of 6 feet diameter and 11 inches breadth was moulded in 24 hours by two men; and a spur wheel of 9 feet diameter and 8 inches breadth, weighing 2 tons, was also moulded in 24 hours by two men.

Mr. Scott exhibited a specimen of the wheel moulding machine, and showed its operation in moulding the teeth of wheels; and also exhibited samples of castings of spur and bevil wheels moulded by the machine.

The Chairman observed that in moulding bevil wheels by the machine the slight taper from the crown to the base of the teeth in the pattern had the effect of easing the pattern from the sand at the moment of beginning to withdraw it, and caused it to clear the mould at once, so that there would not be any risk of shaking or disturbing the tooth which had been last moulded in the previous operations; but in the case of spur wheels, where the pattern had not this advantage of easing itself from the sand in withdrawing, he enquired whether any difficulty had been experienced from the hinder tooth of the pattern interfering during the withdrawal with the truth of the tooth last moulded.

Mr. Scott replied that all risk of damage from that source in the moulding of spur wheels was provided against by making both the teeth of the pattern with a little taper on their outer side, so that the pattern did not touch the last moulded tooth except just at the level of the top of the mould, and cleared itself immediately it began to be withdrawn. There was thus no second smoothing of the sides of the sand teeth after moulding each tooth in the first instance.

The Chairman enquired how many of the machines were now in use, and what was the cost of the two sizes of machine mentioned in the paper.

Mr. Scott replied that there were now sixty of the machines in use, since their first introduction about $2\frac{1}{2}$ years ago; and the cost was about £90 for the smaller sized machine, for moulding wheels from 12 inches to 5 feet diameter, and £120 for the larger size, for diameters from 20 inches to 12 feet. The object of the machine was to enable all engineers to make their own wheels on their own premises at a very small outlay, and exactly in accordance with the requirements of any case that might occur.

Mr. E. A. Cowper said he had seen this wheel moulding machine at Messrs. Maudslay and Field's works in London, where it had been

in use for several months; and he understood that it was in constant use in the foundry and had proved completely satisfactory in working. He had himself experienced the great advantage of obtaining toothed wheels moulded by machinery, instead of by a pattern drawn by hand, on account of the superior accuracy thereby obtained in the teeth; and by the machine described in the paper this advantage could now be obtained in all iron foundries. In regard to the mode of preparing the bottom part of the mould by means of the strickling board before beginning to mould the teeth, as described in the paper, he supposed that in afterwards moulding the teeth it was requisite to break up the smooth face of the sand at the time of moulding each tooth, in order to ensure the new sand in the tooth binding with that in the mould previously smoothed.

Mr. Scott said that in moulding each tooth the face of the old sand was disturbed, which made the fresh sand in the tooth unite completely with it.

Mr. H. H. Grierson observed that, although in the case of only one or two castings being required from the same pattern it might be preferable to mould by the machine from the small pattern, moulding only a single tooth at a time, he thought that when three or more castings were wanted from the same pattern it would be found more profitable to make a complete pattern for the purpose, on account of the saving then effected in cost of labour and in the time of moulding, by getting a number of moulders at work simultaneously round the circumference of the complete pattern. Under such circumstances he thought the only advantage attending the machine would be in drawing the pattern by mechanical means instead of by hand.

Mr. H. Woods thought that, even if a complete wheel pattern were drawn from the sand by a machine instead of by hand, it was a question whether it could be drawn as well as the small pattern containing only the space for a single tooth; and he considered there was always a great deal more liability to a break-down in the mould in drawing a complete pattern.

Mr. W. Ford Smith considered that wood patterns should not under any circumstances be used for moulding toothed wheels, on

account of their liability to continual change of shape, arising from variations in the humidity and temperature of the atmosphere, which caused the different pieces of wood composing the pattern to warp and shrink, principally across the grain of the wood. For small wheel castings up to a certain size he considered it desirable to mould the wheels from machine-cut metal patterns correctly turned; and above the size at which the patterns became too unwieldy to draw readily from the sand, the next step should be to employ a moulding machine that would produce a perfectly cylindrical or concentric mould, free also from any irregularity or twist. The accuracy of metal patterns was not affected by changes of the atmosphere; but even with these it was advisable to draw them from the sand by some mechanical means.

Mr. H. Woods observed that the dividing disc for spacing out the teeth of the wheel in the mould appeared rather small in diameter for moulding wheels of large size; and he enquired whether any difficulty was ever found to arise in spacing out the teeth correctly round the circumference of a large wheel, as a very slight error in the spacing of each tooth would become a serious amount when multiplied by a large number of teeth. He asked also whether the accuracy of spacing was dependent in any way upon the eyesight or skill of the moulder using the machine.

Mr. Scott replied that the dividing disc and the several change wheels were carefully tested in the construction of each machine, so as to ensure the correct spacing of each tooth round the entire circle; and a list was furnished with the machine of the arrangement of change wheels and the number of turns to be given to the handle on the dividing disc for the pitch of every size of wheel required to be moulded within the range of the machine. Except by alterations of the change wheels and of the number of turns on the dividing disc, the moulder had no means of altering the spacing of the teeth; and the accuracy of the spacing was therefore not dependent upon his skill in using the machine. A second tooth could not be moulded unless the pattern went down into its place correctly after the previous tooth was completed; so that any error in turning the dividing handle was at once apparent.

With regard to the relative economy of moulding from the small pattern segment or from a complete wheel pattern, where a number of castings were required from the same pattern, he had had as many as 32 bevil wheels made from one of the segment patterns, and had found the cost had been less than if a complete pattern of the whole wheel had been made for the purpose, taking into consideration the wear and tear of the moulding machine on the one hand, and on the other the rental for the storage of a stock of complete wheel patterns. There was besides this the advantage that the castings moulded by the machine were superior in accuracy, both as regarded the pitch of the teeth and the truly circular shape of the circumference of the wheel.

Mr. H. H. Grierson did not think the castings moulded by the machine were superior in accuracy to those moulded from patterns having the teeth cut by machinery; and the actual moulding of the teeth would evidently occupy a longer time in moulding from the segment pattern of only a single tooth than when a complete pattern was used with a number of moulders at work upon it simultaneously. He understood that a difficulty had been experienced in some cases in introducing the moulding machine, from the men objecting to work with it; and he enquired how far that had been the fact.

Mr. Scott said he had not heard of any difficulty from that source, nor had any objection arisen against the use of the machine in any instance that he was acquainted with. As to the time occupied in moulding by the machine, he had found that in moulding wheels with box arms of H section, which involved extra work in the ordinary way of moulding, the total men's time occupied upon the entire wheel was not greater with the machine than with a complete pattern, though of course the moulding would be done with more expedition where a number of moulders could work simultaneously upon it.

Mr. W. Lloyd enquired whether an ordinary moulder would be able to work the machine without special instruction for the purpose.

Mr. Scott replied that any moulder was able to use the machine at once, and the machines had been introduced at various foundries without giving the men any instructions how to work them, except as regarded the alterations of the change wheels for different sizes of castings.

Mr. E. A. Cowper said that in the case of the moulding machine supplied to Messrs. Maudslay he understood it was got to work on the same day that it was received, without any difficulty whatever being experienced.

The Chairman observed that, although the use of complete patterns for toothed wheels might still continue general, the machine gave a ready means of moulding wheels with great accuracy, and apparently with as much economy in labour as if a complete pattern were employed.

He proposed a vote of thanks to Mr. Scott for his paper, which was passed.

The Meeting then terminated.

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